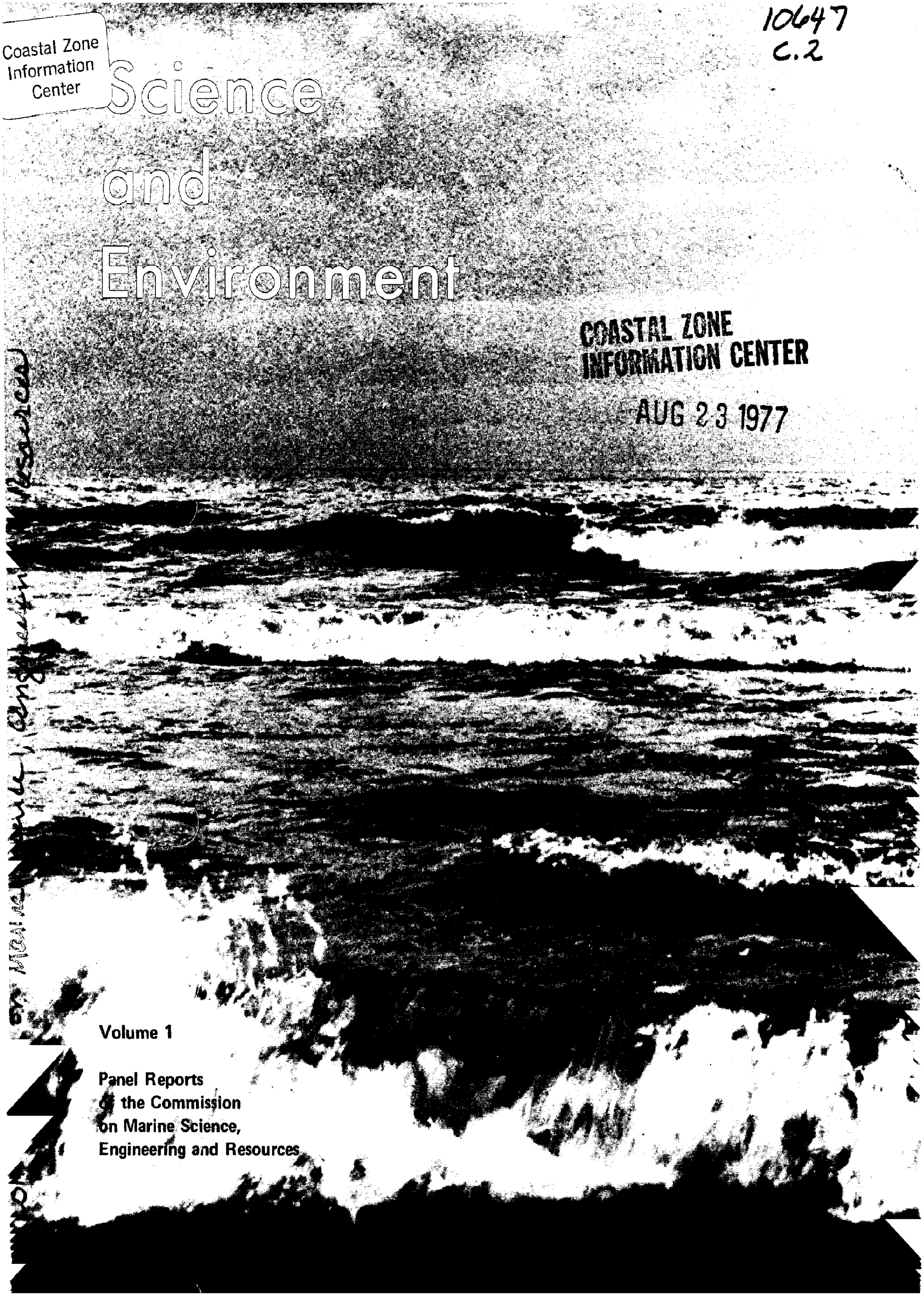

Science and Environment

Volume 1

**Panel Reports
of the Commission
on Marine Science,
Engineering and Resources**

Science

and

Environment

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Panel Reports of the Commission on Marine Science, Engineering and Resources

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The task which faced the Commission on Marine Science, Engineering and Resources was one of unprecedented complexity and scope–to "make a comprehensive investigation and study of all aspects of marine science in order to recommend an overall plan for an adequate national oceanographic program that will meet the present and future national needs."[1] To meet this assignment, the Commission necessarily needed to reach outward to tap the best thinking in a host of disciplines and fields of interest and to array volumes of specialized data.

The Commission approached this task by forming seven working panels from its membership. Each of the panels, aided by staff and consultants, assumed responsibility for a major area of interest: basic science; environmental problems; education, training, and manpower; industry and private investment; marine engineering and technology; marine resources; and international aspects of marine activities. Thus the panels were the principal mechanism for assessing the status of marine matters, for identifying opportunities and problems, and for proposing measures to be taken. The reports prepared by the panels constituted the primary source material upon which the Commission based its own final conclusions.

Throughout the period during which the panels conducted their separate studies, the Commission met as a whole to review and evaluate critically the findings and recommendations of these task forces. The continuing discussion and review assisted the panels in identifying needs for additional information, for clarification, and for reassessment of tentative views; they provided a means for coordination of panel activities; and, most important, they served as an educative process that prepared the Commission as a whole for the preparation of its final report. However, it was recognized from the outset that it was neither necessary nor desirable for the several panels to reach total consistency in their proposals or for the proposals to be fully consistent with positions later taken by the Commission as a whole. Although the panels have been guided in their work by the comments of the entire Commission, each panel is solely responsible for its own report. In considering the recommendations advanced by its panels, the Commission adopted some without modification, rephrased or modified others and, in some cases, took no position.

During their investigations, panel members and staff contacted more than 1,000 individuals, many of whom made major contributions to the preparation of these reports. The Commission is deeply indebted to its panels for the thoroughness and comprehensiveness of reports. The panels in turn wish to acknowledge their debt to the many contributors to the work.

Julius A. Stratton

J. A. Stratton
President

February 9, 1969

[1] P.L. 89-454.

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Chairman
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U.S. Representative

Charles Z. Mosher
U.S. Representative

[1] Affiliation as of time of appointment.

[2] Appointed July 21, 1967 to succeed Robert H. B. Baldwin, former Under Secretary of the Navy, who served as a member of the Commission from Jan. 9, 1967 to July 31, 1967.

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Contents

Marine affairs embrace a multitude of interrelated activities and interests which defy simple categorization or analysis. The term embraces several broad areas of program interest–the coastal zone, development of marine resources, exploration and understanding of the total global air-sea envelope, and provision of services–which became the major categories used by the Commission in organizing its report. However, attention was also necessary to the many activities contributing to the achievement of each of these programs: to basic science, fundamental and applied technology, manpower development, and observation and prediction systems. Appraising and planning the national effort also required consideration of the purposes to be served by each activity and program and of the institutional arrangements for action, including both national and international law and organization; private industry; academic institutions; capital markets; and Federal, State, and local governments.

The assignments of the Commission's panels represent a necessarily arbitrary division of the Commission's total field of interest. To assure that as many perspectives as possible were brought to bear on each problem, the assignments were intended to be somewhat open-ended, and it was not uncommon for several panels to approach similar matters from their several viewpoints. Thus an interest in the economic payoffs from marine activity appears in all the panel materials. The status of marine industries is reviewed in the Report of the Panel on Industry and Private Investment; opportunities for improved returns through application of new technology are considered by the Panel on Marine Engineering and Technology; industrial efficiency in meeting resource needs is considered by the Panel on Marine Resources; and so forth.

Another matter of common interest was consideration of the most appropriate Federal organization to carry forward an expanded marine program. Recognizing that its organization plan must necessarily meet a variety of needs, the Commission did not establish a separate panel to investigate this subject but reserved it for consideration by the Commission as a whole. However, the Commission encouraged all panels to identify organizational implications of their proposals. This commentary is included in their reports.

The field work of the panels was concentrated largely during the period September 1967 through March 1968. Report preparation continued during the spring and summer, with the cutoff date ranging from October to December for panel materials.

Because preparation of panel reports preceded the Commission's final statement, findings and recommendations of the panels differ in some cases from those advanced in the Commission report rendered Jan. 9, 1969, to the President and the Congress. For example, the Panel on Marine Engineering and Technology suggests 15 National Projects. In reviewing the Panel's proposals, the Commission selected five projects for immediate implementation and recommended five for more detailed feasibility studies. Further, the Commission redefined the concept of "National Project" to embrace an additional project–construction of test facilities, which had not been so defined by the panel–and recast five panel National Projects as recommendations for applied technology programs to satisfy related needs identified by other panels. Such shifts in emphasis and terminology were a natural result of the Commission's distillation of the great variety of panel recommendations.

Although the Commission did not adopt all elements of its panel reports, the studies provided valuable background material for its report, "Our Nation and the Sea," and will be valuable to all who wish to examine further the many aspects of our nation and the sea.

Part I

Report of the Panel on Basic Science

Contents

The Panel on Basic Science and Research gathered information through public hearings across the Nation, in concert with the Panel on Environmental Problems; through correspondence with a cross-section of the industrial, academic, Federal and State scientific communities; from authoritative reports reflecting the expertise of groups which have previously explored the topic; and from a variety of interviews conducted by members of the panel, its staff, and consultants.

More than 175 replies were received to letters sent to approximately 500 persons whose knowledge and opinions of the problem were solicited.

The panel also is indebted to the authors of the following reports, from whose pages substance was given to its own efforts:

Effective Use of the Sea, Panel on Oceanography, President's Science Advisory Committee, June 1966.

Oceanography 1966 – Achievements and Opportunities, National Academy of Sciences/National Research Council, 1967.

Marine Science Affairs – A Year of Transition, First report of the President to the Congress on marine resources and engineering development, February 1967.

The Ocean Science Program of the U. S. Navy, Office of the Oceanographer of the Navy, June 1967.

Marine Science and Technology: Survey and Proposals, Report of the U. N. Secretary General to the Economic and Social Council, E/4487, April 24, 1968.

The Oceanographic Operations Program of the U. S. Navy, Office of the Oceanographer of the Navy, December 1967.

National Marine Sciences Program, hearings before the subcommittee on oceanography of the Committee on Merchant Marine and Fisheries, House of Representatives 90th Congress, 1968.

Marine Science Affairs, A Year of Plans and Progress, Second report of the President of the Congress on marine resources and engineering development, March 1968.

The Role of Academic Institutions in the Development of Marine Resources and Technology, Report of the Council of Oceanographic Laboratory Directors, Sept. 12, 1967.

In addition, the National Academy of Sciences Committee on Oceanography contributed a lengthy updating of its report *Oceanography 1966* for the use of the panel.

Public hearings were held in Washington, Boston, New York, Miami, Chicago, Houston, La Jolla, and Seattle, with testimony by representatives of Federal and State agencies, universities, industry, and others. It is not possible to acknowledge all those whose contributions are represented here; they number more than three hundred. Without their help, this report could not have been compiled. The panel expresses its sincere gratitude. However, we would especially like to express our deep appreciation to the consultants who worked closely with us: Dr. Karl K. Turekian of Yale University; Dr. H. W. Menard and Dr. Walter Munk of Scripps Institution of Oceanography; Dr. W. I. Aron of The Smithsonian Institution, and Dr. W. D. McElroy of Johns Hopkins University.

In addition, we would like to single out others for their special assistance: Dr. S. F. Singer, Deputy Assistant Secretary of the Interior; Dr. M. B. Schaefer, Science Advisor to the Secretary of the Interior; Dr. R. Revelle, Director of The Center for Population Studies, Harvard University; Dr. J. Calhoun, Chairman of the Committee on Oceanography, National Academy of Sciences; Dr. J. Lyman, consultant; and Mr. R. Vetter, Executive Secretary of the Committee on Oceanography, National Academy of Sciences.

This report could not have been written without the dedicated assistance of our Executive Secretary, Mr. John Dermody. Details of our hearing schedules and the names of our witnesses can be found in Appendix B.

Dr. Robert M. White, *Chairman*
Dr. John A. Knauss

I. INTRODUCTION

Our understanding of the oceans is severely limited. The imperatives of our time, however, dictate that we turn to the oceans to seek solutions to problems which are acute today and which will become more intensified. The panel has sought to clarify the present state of basic marine science and to assess its relationship to the Nation's needs as a step toward the formulation of a coherent National policy designed to serve not only the needs of the hour but those of the future. The panel is impressed with the way the marine science enterprise has been conducted but it also finds a need for change. The ways of the past and present cannot meet the needs of the future.

A lack of understanding of marine processes constitutes a bar to action on programs vital to National needs. National security, resource requirements, the protection and welfare of the public, and the need to preserve and use effectively marine estuarine and coastal zones all depend fundamentally upon an understanding of the marine environment.

It is imperative that intellectual and scientific competence be recognized as the touchstone of future greatness. No society can shape the future without it; any great society must be prepared to direct part of its energies to understanding itself and its environment.

In the light of these circumstances, basic marine science has a legitimate claim upon the Nation's science resources.

II. THE MARINE SCIENCE ENTERPRISE TODAY

The marine science enterprise in the United States is vigorous and diversified. Research and development sponsored by the Federal Government accounted for $249.5 million in Fiscal Year 1968, an increase of $55 million over FY 1966.

The Federal agencies principally involved in basic marine science are the National Science Foundation, the Department of Defense, and the Department of the Interior. Other Federal agencies are substantial but smaller participants.

The enterprise has been growing rapidly. Except for the National Science Foundation, each Government agency with an interest in the field undertakes mission-related marine science programs. They also maintain in-house laboratories.

The scientific community is arranged in as complex a manner as the Federal structure with which it is strongly involved. Ocean science is actively pursued in large, small, old, or new institutions, in recognized oceanographic institutions, and in classical science departments at universities.

Scientists applaud the diversity of science funding; but they foresee a need for arrangements to accommodate "big science" and they see no mechanism capable of meeting its demands.

The marine science enterprise, in short, is healthy, energetic and diversified in comparison with a decade ago. It is beset with the normal strains of a quickly growing field. The panel also finds, however, that current National financial stresses are beginning to inhibit its growth. The period of rapid growth of the first half of the decade of the sixties has stopped.

III. BASIC SCIENCE–KEY TO UNDERSTANDING OUR PLANET

Our physical home is a composite of interacting earth, sea, sun, and air, and an understanding of the oceans as a major link in the indivisible whole is vital to any real comprehension of the planet. Many of this planet's secrets lie locked in the seas.

While interest in ocean science has been growing, its origins have been largely pragmatic; hence the pursuit of understanding has been automatically relegated to a lower priority in the national effort. Understanding our planetary oceans is a vital goal of the marine science effort.

Recommendation:

The Nation should establish as a major goal the advancement of an understanding of the planetary oceans as a principal focus for its basic marine science effort. The proposal by President Johnson for an International Decade of Ocean Exploration

is an excellent concept through which this major goal can be achieved.

IV. BASIC SCIENCE–KEY TO ACTION

The principal programs advocated by the Commission go to the heart of important segments of our National life. They would be seriously impeded–and in some cases defeated–by ignorance of basic oceanic processes. The acquisition of fundamental knowledge represents the only hope of success.

A. Basic Science and the Near Shore Waters

The effective use of U.S. coastal and estuarine zones and the Great Lakes is among our most urgent marine problems; these are some of the most valuable areas in the Nation. There are many conflicts among uses and users, and a prerequisite for any rational use of these waters is an understanding of the consequences of one use on others. In many cases, necessary knowledge is lacking and here the panel senses a great need for action.

Recommendation:

A much expanded basic research effort should be instituted in all marine science problems related to estuaries, coastal zones and the Great Lakes, the effects of pollution, and the effects of changes in the physical system on living resources.

1. Changing the Shape of the Coast

Much of our coastline is considered poorly protected or endangered, although the Nation has invested substantially in its upkeep. It is being eroded both by nature and man. It is necessary to predict more precisely the consequences of nature's actions and man's. There is a requirement to know much more about the physical processes that shape our coastlines and estuaries.

Recommendation:

Each Federal agency concerned with near shore waters should devote a considerably higher per cent of its funds to basic research in the physical processes which shape our coastlines and estuaries. This will insure the availability of essential knowledge necessary to plan and implement programs for their protection and preservation.

2. Polluting the Waters

Man has brought profound upheaval in the natural balance of our environmental forces, an upheaval which perils his own well-being and which may pose even greater danger in the future. Environmental changes are usually gradual but they are also seldom soon reversible simply by ceasing the activities that generated them. The estuaries and the Great Lakes are seriously affected by waterborne pollution.

Attack on these problems must be accompanied by an increased level of basic research on the dynamics of estuarine waters, identification of pollutants, and the tracing of their effects. The problem of marine pollution cannot be solved in isolation from the more general problem of wider waste management and control. Whatever solutions are proposed for the whole spectrum of environmental pollution, key elements of knowledge must be available on the processes in estuarine and near shore environments.

Recommendation:

The Nation should undertake a much enhanced program of basic research into the dynamics of estuarine waters, the identification of specific pollutants and the tracing of their effects, both on individual species and ecosystems, and on the mechanisms through which organisms in the estuarine ecosystem take up and accumulate various kinds of pollutants.

3. Fish Habitats

The conservation and management of fisheries is vitally dependent upon knowledge of the near shore environment as habitats. The relationship of the biota to physical changes in the estuarine environment constitutes a major problem. Careful research on habitat preference and the effects of natural and man-made disturbances are needed.

Such information cannot be obtained over the short term. The Nation needs natural laboratories for long-term study of the rhythms and relationships governing the estuarine environment. It is urgent that the Nation set aside enough such estuaries to provide these natural laboratories.

Recommendation:

Specific representative sites should be selected for careful, prolonged study to permit the accumulation of basic knowledge essential for understanding the statics and dynamics of the coastal regime.

B. Development of Living Resources

Providing food for a burgeoning world population is one of the most critical problems facing mankind. Insuring adequate supplies of fish can contribute in significant ways to the solution of these problems.

1. Fisheries—Traditional and New

Efficient management of traditional fisheries depends upon additions to basic understanding, particularly the relationships between environmental conditions and infancy and egg survival. It is necessary to understand the interaction of competitor-predator systems. Better correlations between environmental conditions and fish abundance, accompanied by better monitoring and prediction, should enable fishermen to work more productively and efficiently.

The most urgent need for scientific information in new fisheries is for rapid means of stock assessment.

Recommendation:

A continued and expanded effort should be directed toward achieving a basic understanding of such key problems as fish population dynamics, the effect of environmental conditions on fish population, and the dynamics of multi-species systems under predation.

2. Aquaculture

Progress has been severely limited by the lack of information on the genetics and breeding of potentially valuable species, food requirements of juvenile organisms, disease, and optimum environmental conditions.

Recommendation:

Major new efforts directed toward the understanding of the reproduction, growth, and development of potentially exploitable marine organisms should be undertaken to provide the base of understanding and technology necessary to make the products of aquaculture more available.

C. Development of Mineral Resources

The principal limitations are in technology, exploration, and economics. Further exploitation depends to a great degree upon the preparation of adequate inventories. The principal needs are for topographic, geophysical, and geologic mapping and charting.

Little is known about the mechanism of formation of materials on the deep ocean floors, especially the ferro-manganese nodules.

Recommendation:

The basic science effort required to achieve the understanding of the planet (see Basic Science—Key to Understanding Our Planet) should be supported as a necessary National effort to provide the basic geological and geophysical knowledge of the oceans required for the National program of marine mineral resource development.

D. Environmental Monitoring and Prediction

The need for an environmental observation and prediction services goes far beyond marine interests, although they are vitally concerned. Three major problem areas require immediate expansion of basic research: The interchange of matter and energy between sea and atmosphere, the dynamics of ocean currents, and the nature of different scales of motion in the sea. Environmental monitoring is technology-limited; environmental prediction is science-limited.

Recommendation:

Extensive field experiments should be conducted to describe physical processes associated with ocean fluctuations. Parallel efforts in geophysical fluid dynamics should be mounted which can provide the theoretical and practical framework for the establishment of physical techniques for ocean prediction.

1. Air-Sea Interaction

Many types of exchange between ocean and atmosphere need to be studied in detail. This information is important in terms of our ability to predict the state of the oceans, on the one hand, and the state of the atmosphere on the other.

Recommendation:

The Nation should continue to place a high priority on comprehensive field experiments to understand air-sea interaction processes.

2. Dynamics of Ocean Currents

An attack on the problems of predicting fluctuations in major ocean currents will require both extensive series of field observations to describe their actual behavior in nature and supporting research in geophysical fluid dynamics to account for the observed properties of the currents in terms of the inputs of thermal, tidal, and wind energy on a rotating earth. It is time to marshal the Nation's scientific and technological capabilities to plan comprehensive attacks on outstanding problems of ocean circulation dynamics, both in the field and in the laboratory.

Recommendation:

The Nation should undertake a series of systematic investigations into the oceans' current systems to study their dynamics through cooperative field investigations, marshalling at one time multiple ship, buoy, and aircraft arrays, as well as an expanded effort in the theoretical and mathematical modelling of such systems.

3. Scales of Motion

A complex pattern of small scale motions appears to be responsible for most mixing in the sea. Further investigation is needed to account in detail for the mechanisms by which they are produced and by which energy is transmitted from one type to another. The time appears to be at hand when technology will permit a major assault on this problem.

Recommendation:

There should be initiated as soon as possible a well-defined program to study oceanic scales of motion and such a study should be one of the early foci for the test of the elements of the National buoy program.

V. BASIC MARINE SCIENCE AND NATIONAL SECURITY

The Nation's security has been fundamentally tied to the ability of its Navy to operate in and under the sea. There is hardly an area of marine science which does not bear directly on the effectiveness of its operation. It is largely through the Navy's support that the Nation's eminence in basic marine science is maintained. The Office of Naval Research has played a historic and unique role in the Nation's marine science growth.

The effectiveness of tomorrow's Navy will be determined in large part by the level of scientific and technological understanding of the marine environment and all aspects of basic science in this area are of immediate and long-term concern to it.

The panel strongly urges that the Navy take the broadest possible view of its obligations to support basic marine science.

Recommendation:

The Department of Defense should continue to recognize, as it has in the past, the vital nature of all aspects of basic marine science research to its naval missions, and adopt the broadest possible view of its obligations to insure that the National basic marine science effort meet not only its short-term needs but all possible future requirements for marine information. It also should continue to function as one of the cornerstones for the support of the Nation's basic marine science effort.

Acoustical energy is known to propagate over long distance in water; electromagnetic energy does not. Our capability to develop techniques and equipment which will enable us to use acoustical energy as a basis for detection depends on our knowledge of how the ocean structure affects such energy propagation.

The Navy has given prime attention to this area, and its detection capabilities are formidable. The importance of the problem cannot, however, be overstated. The panel, recognizing the extensive

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effort now maintained by the Navy in the field of underwater acoustics, nevertheless feels that our understanding of the inhomogeneities of the ocean, the effect of the biota and the boundary between air and water, and the effects of bottom topography in terms of acoustic scattering, reflection, and refraction, can be significantly improved through additional research.

Recommendation:

The Navy should maintain and, as required, expand its underwater acoustic research program.

VI. TECHNOLOGY AND MARINE SCIENCE

Basic science and marine technology have failed to achieve the level of partnership necessary to the advancement of many fields of marine science. Only marginal attention is paid to provision of the kind of modern engineering support required by the growing problems of ocean science, although industry has a vigorous marine and general engineering competence. Too few engineers have been brought into the field to work on basic science problems, although much technology and engineering developed for other purposes is susceptible to marine science use. This lack is limiting development in some areas. The marine science community seems to be willing simply to use whatever technology is available. Basic marine science has important needs for special technology, and should recognize the fact and make the needs known.

Recommendation:

Efforts should be initiated to increase participation of the private sector in instrument development and other marine engineering work. The major academic institutions should establish, or insure access to, groups with advanced engineering competence to work closely with marine science groups. Some technology development should be encouraged purely for the achievement of a better understanding of the oceans.

VII. EDUCATION AND TRAINING

The Nation has a healthy program of graduate training in marine science, sufficient to support an immediate expansion in basic science. Nevertheless, over the long term, a fully developed national program of basic research must be accompanied by an adequate level of trained manpower.

The basic science effort is not limited by the availability of research manpower trained at oceanographic institutions; a great many researchers receive their doctorates in other disciplines. An important part of the arrangements for an expanded program of professional training must be provision for support of postdoctoral programs at marine science research centers.

The supply of oceanographic technicians, particularly of sea-going technicians and those competent to operate and maintain sophisticated research devices, is likely over the short term to prove the most critical manpower area in the field.

Recommendation:

The major educational institutions should be encouraged to maintain the vigor of graduate and postdoctoral programs; estuarine and coastal research centers should develop appropriate training programs in their specialties; additional training programs for marine technicians should be created.

VIII. INSTITUTIONAL NEEDS

Available institutional arrangements are extremely diverse, and represent a sound base on which can be built other arrangements to meet growing needs. They are, however, not now adequate to a task of the magnitude envisioned by the panel. There is emerging a need for arrangements designed to cope with the problems of "big science" and those of a local nature.

It is in the general area of facility support that the panel sees some of the greatest obstacles facing the research community today.

A. The Need for Diversity

Important discoveries have been made virtually across the spectrum of scientific institutions. There is no one best way to produce oceanographic scientists or oceanographers. It would be a mistake to support one institutional arrangement to the exclusion of the others. It would be incorrect to suggest that all or even most progress will be made in a single class of laboratories or by persons with a particular type of training. There is a need for various kinds and sizes of marine laboratories in the Nation.

Recommendation:

The present variety of institutional arrangements for the development and support of oceanography is good and should be nurtured. Furthermore, as the horizons of oceanography continue to expand, new institutional arrangements can be encouraged.

B. University-National Laboratories

A small number of oceanographic institutions—large, well staffed and relatively well financed—have been largely responsible for U.S. leadership in marine science. They represent a major National investment. In planning institutional arrangements, it is in the National interest to build on present sources of strength and experience. These outstanding institutions will remain a vital part of the base, and will be centers around which rapid and energetic growth can occur.

There is a need for large laboratories equipped to undertake any tasks of a global, national or regional nature, and to institute new and imaginative programs.

The Nation should designate a small group of institutions which should include, but not be restricted to, those which today provide the National leadership as "university-National laboratories." They should be distributed geographically to cover different parts of the ocean effectively and should receive adequate "institutional support," in return for which they would serve the needs of those affiliated with other scientific institutions.

The laboratories should contain the necessary engineering staffs and support facilities, or should be able to arrange for close affiliation with engineering groups.

Recommendation:

A small group of institutions, which should include but not be restricted to the acknowledged leaders, should be designated "university-National laboratories." They should be distributed geographically to cover different parts of the ocean and should be provided with adequate facilities for undertaking global deep ocean programs in basic science. Their facilities should be available to scientists at other universities and Federal laboratories for related basic science activities. They should be accorded adequate institutional support for maintenance and operation, and in turn should commit themselves and their facilities to serve needs of scientific groups affiliated with other institutions. Such an institutional arrangement will insure that the Nation's leading oceanographic institutions will be provided adequate resources and support to insure their continued health and vigor.

C. Coastal and Estuarine Laboratories

Coastal lands are some of the Nation's most desirable. The problems of estuaries and near-coastal areas are principally, but not entirely, local or regional.

There is a need for the establishment of coastal zone research institutions in association with appropriate academic institutions to provide the basic understanding of coastal and estuarine processes so that Federal, State, and local governments can have available information on which to base rationally their management procedures.

There is sufficient difference in problems between areas that there should be a university laboratory devoted to basic and applied marine science located on every major estuarine system. The Sea Grant College Program is well suited for the support of the complex of coastal zone laboratories. It is not necessary that they be identical in size and scope.

Recommendation:

A network of estuarine and coastal zone research institutions should be established in association with appropriate academic institutions to undertake the basic and applied research on estuarine processes so that State and local governments can have information on which to base management procedures rationally. These facilities need not be large in size but should have adequate facilities and staff sizes exceeding the critical limit to maintain stable programs. Their activities should be supported under the Sea Grant College Program.

D. Federal Laboratories

Federal laboratories are necessary to provide Federal agencies with the capability for carrying out their missions. If they are to be responsive to the opportunities as well as the needs of basic science, they should continue to devote some of their effort to basic research problems. Such practices are also necessary to attract and maintain a high level of scientific competence within these laboratories.

Agency support for extramural research should avoid competitive struggles over fund allocations between its in-house and its extramural contractors and grantees. Federal research programs need flexibility which only outside grants and contracts can provide.

There is a need for Federal laboratories large enough to meet the Government's requirements. Many Federal laboratories are understaffed and underfinanced. There should be fewer, stronger, adequately equipped and staffed Federal laboratories.

The practice of siting new Federal laboratories close to university centers should be followed.

Recommendation:

Federal laboratories should be strengthened by moving in the direction of fewer but stronger laboratories adequately funded and staffed with even closer affiliation with academic institutions. Steps should be taken to provide an atmosphere in these laboratories conducive to attracting first-rank scientists by providing the necessary flexibility at the scientific leadership level.

IX. FEDERAL SUPPORT SERVICES

Basic marine science depends on the existence of technical support services, usually provided by the Federal Government, to meet many needs beyond those of research. Among the most important are those dealing with mapping and charting, navigation, and data management.

A. Mapping and Charting

The President's proposal for an International Decade of Ocean Exploration will involve extensive mapping and charting of the deep oceans as well as the continental shelves and slopes. The panel's proposal to establish as a major U.S. goal the understanding of the planetary ocean will be closely served by the proposed Decade and its mapping and charting programs will be critically important.

The Federal Government today has no mechanism whereby requirements of mapping and charting for basic science can be accommodated in connection with surveys conducted for other purposes. But with a minimum of additional effort, mapping and charting can, in many instances, satisfy certain needs of basic science. There is a need for mechanisms by which Federal mapping and charting are kept under frequent review by the scientific community to insure that these efforts are also responsive to the needs of basic science.

Recommendation:

The mapping and charting activities of the Federal Government should be made as responsive as possible to the needs of basic science and mechanisms should be established whereby mapping and charting operations of the Federal agencies can be reviewed to insure responsiveness to science needs.

B. Navigation

The Federal Government should establish a precise coastal navigation system which would be available to support scientific research in the oceans. Such a system would be of great utility to many other marine activities. The scientific community should continue to work closely with the Navy in the perfection of the satellite navigation system as a supporting service for research and surveys on the high seas.

The situation with regard to navigation over the outer continental shelves of the United States and in coastal waters beyond the capability of visual methods of position fixing is not as favorable.

Recommendation:

The Department of Transportation should proceed with the installation of a precise electronic navigational system sufficient to cover the entire coasts of the continental United States and Hawaii by the early 1970's and of Alaska and the Bering Sea by the late 1970's.

C. Data Centers

Present systems do not meet the need for a coordinated system of data centers for archiving and retrieving oceanographic information. The efforts of the National Oceanographic Data Center and the Smithsonian Oceanographic Sorting Center and the National Weather Records Center have barely been able to keep up with the present rate of acquisition as well as the demands for data retrieval.

1. National Oceanographic Data Center

The inability of the National Oceanographic Data Center to carry out its mission effectively has resulted from its peculiar nature: funded by several Federal agencies with differing needs.

The Center, while it should be aware of naval requirements and geared to serve the Navy as well as other government agencies, should be located in a non-defense agency, which should budget for and administer the funds necessary to maintain its basic operation in acquiring, coding, and storing data. Costs of work undertaken for non-Federal agencies should be borne by requesting groups to the extent of cost of reproduction.

The storage and retrieval of data that do not primarily vary with time should not be concentrated in a single agency, but should be left in the hands of their principal users.

The National Oceanographic Data Center is not now involved in the management of real time ocean monitoring and prediction systems and should not become so involved in the future.

2. National Weather Records Center

The National Weather Records Center's primary mission is to archive the National and international weather records. Its marine functions include the archiving and retrieval of all ocean weather, sea state, and sea surface temperature data. The National Weather Records Center has suffered over the years from the financial constrictions and is unable to meet fully the growing needs for marine data.

3. Smithsonian Oceanographic Sorting Center

The Smithsonian Oceanographic Sorting Center is a service organization developed in response to the need for expediting the analysis of biological and geological samples. Sorted collections are shipped to specialists located throughout the world, permitting the effective use of the small number of skilled taxonomists. The Center is supported both by direct appropriation and through contracts with several Federal agencies. Present funding levels permit the sorting of approximately 35 per cent of the samples received.

4. A Coordinated System of Data Centers

The needs of basic science for adequate data centers will require that the Federal Government insure that the activities of its principal marine data centers operate as part of a coordinated system. It is now a lengthy and difficult process to combine synoptic data from different data centers.

Recommendation:

The National Oceanographic Data Center, the National Weather Records Center, and the Smithsonian Oceanographic Sorting Center should be adequately supported with funds to enable them to keep up with the growing volume of marine data and to take advantage of modern archiving and retrieval technology. This will permit the establishment of a closely linked coordinated system of marine data centers. The National Oceanographic Data Center should be organizationally lodged in a non-Defense agency to permit it to meet the needs of the entire oceanographic community more effectively. The basic operations of the National Oceanographic Data Center should be funded by the agency in which it is lodged and work undertaken for other agencies should be on a reimbursable basis.

X. FEDERAL AND INTERNATIONAL ORGANIZATION

The panel has sought to determine whether Federal or international organizational arrangements meet the needs of basic science, and to identify organizational conditions representing obstacles to the effort.

A. Structural Issues in Federal Organization

Most scientists are satisfied with present institutional arrangements, but there are difficulties within the structure for acquiring support for facilities, large interdisciplinary programs and engineering development.

New requirements of marine science laboratories for major facility support could be handled through the Navy and the National Science Foundation, given adequate funds. The panel, however, fears that the Foundation may become so overcommitted to capital facility and institutional operation support that its flexibility would be limited.

Recommendation:

The major civil responsibility for providing institutional and facility support should be invested in the new agency recommended by the Commission. The National Science Foundation should be relieved of this responsibility. The Office of Naval Research should continue to provide the kinds of support it has in the past. Other Federal agencies should provide limited institutional and facility support.

B. Structural Issues in International Organization

Marine science affairs will ultimately require an intergovernmental body at the treaty level, perhaps as a separate specialized agency of the United Nations. The Intergovernmental Oceanographic Commission needs strengthening.

Recommendation:

Immediate steps should be taken to strengthen the Intergovernmental Oceanographic Commission as the principal intergovernmental forum for marine science and to facilitate its collaborative efforts with other international intergovernmental groups. As an ultimate goal, a separate treaty organization should be established within the United Nations system for marine science and other suitable marine applications.

C. Funding Support

Every Federal agency which is responsible for marine research and maintains in-house capability should strike a reasonable balance between in-house and out-of-house basic research. The ratio will vary, but within the basic research category a target of 50 per cent for each is reasonable. Competition should be minimized by establishing within each agency a separate office for out-of-house research programs.

The new agency recommended by the Commission should create an office to fund institutional grants, facility support and engineering development.

The specific programs recommended in this report clearly indicate that an increase of basic science funding is required to achieve the essential base of knowledge about the ocean environment for presently anticipated and future unanticipated uses.

While it is difficult to assess the exact cost of this expanded effort, an analysis of the programs indicate that incremental funding for the 1970's should show an annual increased spending level of approximately $200 million. Forty per cent of this increased funding would be for capital and operating requirements of the university-National laboratories, 10 per cent for the coastal laboratories, 15 per cent for in-house Government laboratories, and the remaining 35 per cent for increased Federal funding of other out-of-house research by the various agencies.

Recommendation:

The basic science effort of this Nation must be maintained and expanded to encompass the programs described in this report. To achieve this an incremental increase of approximately 20 per cent per year for operating and capital expenditures should be maintained until the current basic science funding base has increased by $200 million annually.

Many institutions should continue to operate their own vessels. The Panel does not concur with the President's Science Advisory Committee that all fleets be regional. The panel's previous recommendation to designate university-National laboratories will provide regional specialized facilities such as special purpose ships.

. . . an unknown world at our doorstep . . . our last frontier here on earth . . .

President Lyndon B. Johnson

The global sea is indeed, as President Johnson has said, our final earthly frontier. Throughout recorded history, it has given much. We sail the seas; we fish them; we extract the oil beneath their depths. We struggle to protect ourselves against their hazards. We strive to learn their secrets. But an understanding of our oceans is severely limited; they still retain the aura of the mysterious.

The imperatives of our time, however, require that we turn to the oceans to seek solutions to problems which are already acute today and will inevitably be intensified. Much of the world is hungry, and we must look to the oceans to help satisfy that hunger. An ever-increasing need for minerals presses inexorably upon us, but we know little of where, when, why, or in what quantity the riches of the ocean exist, or at what cost of extraction. Except for isolated instances, our lack of knowledge is a source of concern.

As we crowd one another in our cities and seek more land for housing and industrial development, we crowd our near shores and estuaries. We dredge channels for harbors, and bury our oyster beds. We fill our wet lands and destroy the breeding grounds for marine organisms. We use the water to dump our wastes and in the process kill our fish. We flock to our coastline and expose ourselves to the storm surge and the hurricane. We build dams and breakwaters, and upset the equilibrium of our beaches.

Figure 1. *Miami Beach, Florida, September 1947. A hurricane-driven wave towering many feet into the air smashes at approach to Baker's Hanlover Bridge just north of Miami Beach as the tropical hurricane struck in full fury at the coastal resort city. (ESSA photo)*

We are confronted today with many imperatives which in turn raise an infinity of questions. Answers are to be found only through understanding of the complexities of the interacting land, sea, and air and the biological and geological resources which are sustained by the rhythms and cataclysms of nature.

High on the list of these imperatives is the defense of our Nation in a time of surpassing technology which has changed the oceans from a vastness of protection of our borders to a medium of stealth and menace. We must be able to detect and defend against undersea weapons of enormous destructive power. To detect, we must know how energy propagates through the fluid, how it is affected by the sea bottom and by living creatures.

The surge of technology also compels us to confront a host of new problems whose solution will depend on the direction and vigor of our basic science effort. Paradoxically, the greater our technological capabilities in the oceans become the greater the basic science problems become.

Development of marine protein concentrate creates a need to insure adequate sources of raw material; it is necessary to develop better understanding of the nature of organic matter in the sea, and its transfer through the food web. To increase man's ability to live and work ever deeper in the sea, it is necessary to learn more of hyperbaric physiology. The proposed use of nuclear energy to create new harbors, modify shorelines, or dig canals demands new knowledge about possible long term ecological effects. The building of dams brings the necessity for better understanding of the supply of riverborne sediments and the consequent loss of beach sand. The technological ability to change or regulate the flow of fresh water into estuaries requires more knowledge of estuarine circulation.

The National enterprise in marine science has not lacked its studies, analyses, assessments and recommendations in the past. A steady stream of reports from such authoritative bodies as the National Academy of Sciences[1] and the President's Science Advisory Committee[2] have reviewed, criticized, and recommended action. These reports can be said to have borne fruit, as indicated by the growth in the National investment in the marine enterprise. They have also provided a basis for critical evaluation by the panel, and without them its work would have been infinitely more difficult.

Given these reports, the panel undertook to ask and answer policy questions which it believed were of overriding importance to the Nation's marine science posture. This was done through public hearings, eliciting the information and opinions from leaders in the field, and from various other sources. The panel has sought to clarify the present state of basic marine science, and to assess its relationship to the Nation's needs as a step toward the formulation of a coherent National policy designed to serve not only the needs of the hour but those of the future.

In this task, the panel was confronted with a host of profound questions. What are the Nation's marine interests likely to be for the rest of the century? Are they achievable with our present knowledge and understanding of the oceans? If not, where is our knowledge deficient? Are the deficiencies remediable over the time span? Are they due to a lack of funds or technology, or just basic understanding? Are institutional arrangements at the Federal and local levels adequate to the tasks as perceived? What should be the role of the Federal Government and private agencies in marine science enterprise? How should the Federal Government invest in basic marine science? Where should the investment be made in terms of program priorities? What must be done to insure adequate levels of trained manpower for the tasks ahead?

The panel cannot claim to have answered all these questions, but it hopes that the views and conclusions will provide a useful base from which the nation can move ahead.

There are several overriding impressions. Among them are the vigor and diversity of the National effort; the way it has operated to react to the real needs of the Nation, by its flexibility in some areas and its rigidity in others. In short, the panel is impressed by the way in which the enterprise has been conducted, but it also finds a need for change. The ways of the past and present cannot meet the needs of the future.

Considerable thought has been devoted to determining the right bases for justification of present and projected levels of marine science activity. The panel has taken the following facts into consideration: Lack of understanding of marine processes constitutes a bar to action programs vital to National needs. National security, resource requirements, protection and welfare of the public, and the need to preserve and use effectively the marine environment require achievement of an understanding of marine processes.

We consider it imperative that intellectual and scientific capital be recognized as the touchstone of future greatness. No society can shape the future without it; any great society must be prepared to direct part of its energies to understanding itself and its environment. Understanding the planet Earth is at least as important as understanding the planets of space, and the hope of ultimate return is greater.

With these beliefs in mind, and cognizant both of National financial constraints and the competing claims of all other areas of science, the panel has concluded that basic marine science has a legitimate claim against the Nation's science resources.

[1] *Oceanography 1960 to 1970*, National Academy of Sciences-National Research Council, 1959; *Oceanography 1966*, National Academy of Sciences, National Research Council, Pub. No. 1492, 1967.

[2] *Effective Use of the Sea*, Report of the President's Science Advisory Committee, 1966.

Marine science, like most other science in America today, is a highly competitive field, a field so much in the spirit of the free enterprise system as to be an almost classic example.

It has products, buyers, sellers, and a marketplace. Its customers, for the most part, are Federal agencies; its sellers are scientists and scientific institutions; its products are ideas and programs, and its marketplace is Washington.

In fiscal year 1968, marine research and development in the Federal Government accounted for an estimated $249.5 million, an increase of $55 million over 1966 or approximately a 28 per cent increase in two years. This is exclusive of a $72 million investment in capital facilities such as ships, some of which will be used to support basic science. Funding of the National marine science program for 1966-1968 by various categories is shown in Table 1.

Table 1. PROGRAM PLAN FOR MARINE SCIENCES AND TECHNOLOGY BY FUNCTIONAL AREA (in millions of dollars)

	1966 actual	1967 est.	1968 est.
Research and development:			
Research	122.3	93.5	117.7
Development	72.4	116.3	131.8
Subtotal	194.7	209.8	249.5
Investment:			
Ships	29.4	68.9	22.5
Major equipment	9.1	18.4	29.6
Shore facilities	4.8	14.5	15.2
Other	3.5	2.0	4.5
Subtotal	46.8	103.8	71.8
Operations:			
Surveys	68.9	103.6	101.6
Services	20.1	19.6	23.3
Other	2.9	1.2	1.5
Subtotal	91.9	124.4	126.4
Grand Total	333.4	438.0	447.7

Source: 1967 and 1968 editions of *Marine Science Affairs.*

The major customers within the Federal establishment are the National Science Foundation, the Department of Defense (principally the Navy), the Department of the Interior and its many marine-related bureaus. Other buyers of scientific programs and projects include the Department of Commerce (Environmental Science Services Administration and Maritime Administration), the Department of Transportation (Coast Guard), the Atomic Energy Commission, and the National Aeronautics and Space Administration. The size of the market provided by each of the Federal agencies is shown in Table 2. The Department of Defense by far dominates the market, providing over half the total. However, a significant change can be observed as other aspects of marine science

Table 2. TOTAL FEDERAL MARINE SCIENCE PROGRAM BY DEPARTMENT AND AGENCY (in millions of dollars)[1]

	Estimated FY 1967	Estimated FY 1968
Department of Defense	277.7	256.9
Department of the Interior	64.1	73.5
National Science Foundation	24.8	38.5
Department of Commerce	35.3	38.4
Department of Transportation	8.3	10.7
Atomic Energy Commission	11.3	12.7
Department of Health, Education and Welfare	7.7	6.4
Department of State	5.1	5.0
Agency for International Development	2.0	2.6
Smithsonian Institution	1.6	1.6
National Aeronautics and Space Administration	.1	1.6
Total agency programs	438.0	447.7
National Council on Marine Resources and Engineering Development	(0.9)	(0.9)
Commission on Marine Science, Engineering and Resources	(0.9)	(0.4)

[1] In this and all subsequent tables, details may not add to totals due to rounding.

become of interest to the Nation. The Defense share of the market is dropping. In 1967 Defense accounted for 63 per cent of the total while in 1968 it accounted for only slightly more than 50 per cent.

The market may also be characterized by the funds being allocated to specific programs as indicated in Table 3. Presumably the amount of funding in each program area is a measure of the priority assigned to it in the National effort. The overwhelming importance of National security is quite apparent. The priority assigned to general oceanographic research is gratifying. In 1968 it totaled $78.4 million or nearly 18 per cent of the total National effort.

Table 3. TOTAL FEDERAL MARINE SCIENCE PROGRAM BY MAJOR PURPOSE (in millions of dollars)

	Estimated FY 1967	Estimated FY 1968
International Cooperation and Collaboration . . .	7.1	7.6
Military Security	161.8	136.9
Fishery Development and Seafood Technology . .	38.1	41.2
Transportation	11.9	15.2
Development of the Coastal Zone[1]	21.4	26.7
Health	6.6	5.2
Non-living Resources . .	7.2	8.1
Oceanographic Research[2] .	61.5	78.4
Manpower and Education .	4.0	7.2
Environmental Observation, Prediction, and Services .	24.4	24.5
Ocean Exploration, Mapping, Charting, and Geodesy .	77.4	74.5
General Purpose Ocean Engineering	14.8	18.2
National Data Centers . .	1.8	2.0
Total	438.0	447.7[3]

[1] Includes shore development, pollution management, recreation.

[2] Research beneficial to more than one of the headings above.

[3] .022 per cent increase.

This market has been growing by almost any standards, and the United States occupies a position of global leadership in the field. Tables 4 and 5 show this Nation to be first in numbers of oceanographic research vessels and in marine scientists engaged in research.

Table 4. DISTRIBUTION OF OCEANOGRAPHIC RESEARCH VESSELS BY COUNTRY

Member State Reporting	Number of Research Vessels (15 m. and larger)
United States	188
U.S.S.R.	110
Japan	42
United Kingdom	28
Canada	22
France	18
Federal Republic of Germany.	17
South Africa	12
Denmark	11
Argentina	10
Portugal.	10
Norway	9
Poland	9
Sweden	9
Australia	8
Netherlands	8
Venezuela	6
New Zealand	5
Thailand	5

Source: *Marine Science and Technology: Survey and Proposals*, Report of the Secretary General, United Nations Economic and Social Council, April 24, 1968.

Table 5. COUNTRIES REPORTING 50 OR MORE MARINE SCIENTISTS ENGAGED IN MARINE RESEARCH

State	Number of Scientists
United States	2,000
Japan	1,600
U.S.S.R.	1,600
United Kingdom	650
Canada	509
France	475
Federal Republic of Germany . .	300
Chile	113
Netherlands	95

Table 5 (Continued)

Norway	95
Australia	85
China	81
South Africa	78
New Zealand	71
Argentina	70
Peru	70
Mexico	67
Monaco	50
Sweden	50
Austria	45 to 65

Source: *Marine Science and Technology: Survey and Proposals,* Report of the Secretary General, United Nations Economic and Social Council, April 24, 1968.

The market is also extremely diverse. The marine sciences are important to many agency missions. Except for the National Science Foundation, each Government agency undertakes marine science programs relevant to its own mission.

A summary of the interests of the Federal agencies with responsibilities in the marine area is shown in Table 6. A bibliography of current Federal research programs is given in Appendix A. Except for the National Science Foundation, these agencies also maintain their own research establishments in the form of in-house laboratories; here lies a source of some discontent, for the non-Federal scientific community tends to regard the Federal in-house laboratory as a form of unfair competition.

Table 6. MARINE SCIENCE RESPONSIBILITIES OF THE FEDERAL AGENCIES

Agency	Mission
DEPARTMENT OF DEFENSE	All phases of oceanography relating to national security.
Navy; Advanced Research Projects Agency; Army Corps of Engineers.	Naval technology. Statutory Civilian Responsibilities: Great Lakes, river, harbor, coastal, and ocean charting and forecasting; Great Lakes, river, harbor, and coastal development, restoration, and preservation.
DEPARTMENT OF THE INTERIOR Geological Survey; Federal Water Pollution Control Administration; Bureau of Commercial Fisheries; Bureau of Sport Fisheries and Wildlife; Bureau of Mines; Bureau of Land Management; National Park Service; Bureau of Outdoor Recreation; Office of Saline Water.	Management, conservation, and development of marine natural resources. Measurement and enforcement of water quality standards. Acquisition, preservation, and development of coastal areas. Identification and development of technology for evaluation of mineral resources. Identification of sources and interrelationships for supply of fresh water.
NATIONAL SCIENCE FOUNDATION	Basic and academic oceanography. Facilities support. Sea Grant Colleges and Programs.
DEPARTMENT OF COMMERCE Environmental Science Services Administration; Maritime Administration	Environmental prediction and description; tsunami and hurricane warning. Charting and mapping of coastal and deep-ocean waters. Central responsibility for air/sea interaction program. Research on ship design, shipbuilding, and ship operations. Marine transportation and port systems.

Table 6 (Continued)

Agency	Mission
DEPARTMENT OF TRANSPORTATION. . . . Coast Guard Office of the Secretary	Safety and protection of life and property in port and at sea. Delineation and prediction of ice masses. Navigation aids; oceanographic and meteorological observations. Transport systems analysis and planning.
ATOMIC ENERGY COMMISSION	Radioactivity in the marine environment. Development of marine nuclear technology.
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE . . . . Public Health Service; Office of Education; Food and Drug Administration.	Human health, healthfulness of food, biomedical research, and support of education.
DEPARTMENT OF STATE	United States' participation in international organizations. Support of international fisheries commissions. International marine policies.
AGENCY FOR INTERNATIONAL DEVELOPMENT	Foreign assistance and food resources for developing nations.
SMITHSONIAN INSTITUTION	Identification, acquisition, classification, and ecology of marine organisms; investigations of the geophysical factors of oceanic environment.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	Feasibility, design, and engineering of spacecraft and sensors for ocean observations.
NATIONAL COUNCIL OF MARINE RESOURCES AND ENGINEERING DEVELOPMENT	Policy planning and coordination; assistance to the President.

Source: *Marine Science Affairs,* 1968.

There are currently 85 Federally-operated marine science laboratories distributed along our coasts and Great Lakes. Their distribution by agency and State is shown in Table 7. In addition to this in-house research effort, Federal agencies contract for research from industry and academic institutions, principally the latter. As an example of the wide-spread activity, during the period from 1963 through 1967 the National Science Foundation provided marine science support to 82 different institutions in 38 States.

Table 7. LOCATION AND NUMBERS OF FEDERAL LABORATORIES BY STATES

State	PHS	BCF	BSF&W	USN	ESSA	OTHER	TOTAL
Alabama	1		1				2
Alaska		2		1			3
California		7	1	6		BuMines, USGS	16
Connecticut		1		1			2

Table 7 (Continued)

State	PHS	BCF	BSF&W	USN	ESSA	OTHER	TOTAL
District of Columbia		2		1		Smithsonian, CERC, SOSC, NODC, CGOU	8
Florida		4	1	2	3		10
Georgia		2					2
Hawaii		1		1			2
Louisiana		1					1
Maine		1					1
Maryland		1		4	1		6
Massachusetts		2					2
Michigan		2			1	Lake Survey	4
Minnesota		1				FWPCA	2
Mississippi		1				USCE	2
New Jersey			1				1
New York				1			1
North Carolina		2					2
Oregon						FWPCA	1
Pennsylvania				2			2
Rhode Island	1		1	1		FWPCA	4
Texas		1					1
Virginia				2	1		3
Washington	1	3	1		2	FWPCA	8
Totals	3	34	6	22	8	12	86

Abbreviations

PHS = Public Health Service
BCF = Bureau of Commercial Fisherie s
BSF&W = Bureau of Sport Fisheries and Wildlife
USN = United States Navy
ESSA = Environmental Sciences Services Administration
Bu. Mines = Bureau of Mines

USGS = U.S. Geological Survey
CERC = Coastal Engineering Research Center
SOSC = Smithsonian Oceanographic Sorting Center
NODC = National Oceanographic Data Center
CGOU = Coast Guard Oceanographic Unit
FWPCA = Federal Water Pollution Control Administration
USCE = U.S. Corps of Engineers

Source: Appendix F, *Marine Science Affairs,* 1968.

The Federal Government has established special committees to coordinate and plan the total National marine science effort. Until the formation of the Marine Council, the mechanism was the Interagency Committee on Oceanography of the Federal Council for Science and Technology. The Interagency Committee on Oceanography and, more recently, the Marine Council have made serious attempts to formulate and put in being a National oceanographic program.

The Interagency Committee on Oceanography mechanism was effective for the exchange of information but seriously defective in devising and implementing a coherent National program. Part of the trouble lay within the mechanism itself: its member agencies frequently sought to insure that their own activities were not compromised by committee action. The defects stemming from outside were the judgment of oceanographic programs in the parent department's priority sequence; it meant that agency commitments and interests, when placed in a departmental decision framework, changed in the departmental budget process.

However, by far the most serious defect was the fact that each agency was responsible to a different Congressional appropriations committee. Program coherence could not be maintained through the Congressional appropriation process. The Marine Council has been able to do somewhat better in the formulation of National goals and programs. Being a cabinet level coordinating and planning mechanism chaired by the Vice President, it has had some success in providing a substantial amount of leadership, and within the executive branch programs have retained their coherency. However, it has had no more success than the Interagency Committee on Oceanography in providing cohesiveness of programs through the Congressional process.

Confronting this maze of the Federal marketplace is the marine scientific community, as complex and diverse as the Federal structure it would interest in its programs.

Ocean science is where one finds it; it is found in such prestigious institutions as Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, and Lamont Geological Observatory; in such vital and growing centers such as Oregon State University, University of Miami, and University of Washington; in such smaller laboratories of specialized competence as the Chesapeake Bay Institute of Johns Hopkins University and the Duke University Marine Laboratory.

Some of the best research in the field is done at institutions distinctly removed from the mainstream of marine science such as Yale University and University of Chicago. The number of institutions involved in the field has grown by leaps and bounds. Interagency Committee on Oceanography Publication 30 lists 65 schools which now offer curricula in the marine sciences.[1]

The scientific community, too, has its organizations for the exchange of information and the exercise of concerted action. At the apex of these bodies are the Committee on Oceanography of the National Academy of Sciences, and the National Academy of Engineering Committee on Ocean Engineering.

The prestigious platforms of the National Academies offer the scientific community a means to make its opinions known and its influence felt in the highest councils. It criticizes, reviews, and recommends. Federal agencies are extremely sensitive to viewpoints expressed through the Academies.

None of this alters the fact, however, that the competition of the science marketplace determines which programs are funded, and to what extent. Many scientists have no real knowledge of how to operate effectively within the system. Conversely, those who are aware of its complexities, its rules, and its procedures are in a better competitive position.

Although it is far from a perfect system, this competition is at the heart of the vigor of our marine science enterprise. Given intelligent, knowledgeable management within the Federal agencies—management with a broad view of the needs of science in the Nation—the enterprise can continue to prosper under this system. Because of the influence wielded by a very few Federal managers, every effort should be made to insure continuation of wise, dedicated management at this level.

Scientists, almost to a man, not only approve but applaud the diversity characterizing the funding of the science effort. They view with outspoken alarm anything which to them smacks of centralization.

The fragmentation of the system, however, brings complaints of a lack of flexibility to deal with emerging basic science problems. The Nation's scientists foresee the need for large sea and shore based facilities, requiring large capital outlays, which the splintering of the present market makes it difficult to supply. They foresee an era of "big science," and they see in the present system no mechanism capable of meeting its demands.

The marine science enterprise is in a period of adolescence. The signs are everywhere. Marine scientists spend much time trying to define what they are. They see a unity in all ocean science, but this unifying concept has yet to weld a single strong scientific society which can represent their views or provide a suitable coherent forum for the exchange of ideas or presentation of publications. The fisheries and biology oriented marine scientists belong to the American Society of Limnology and Oceanography, the physical oceanographers and marine geophysicists are organized principally within sections of the American Geophysical Union, and the marine technologists in the new and growing Marine Technology Society. These are but institutional symptoms of some of the problems troubling the science—the lack of rapport between the scientist and technologist, the split

[1] *University Curricula in the Marine Sciences,* ICO Pamphlet No. 30, August 1967.

Table 8. DOCTORAL CANDIDATES AND DEGREES GRANTED AT 29 INSTITUTIONS WITH OCEAN SCIENCE CURRICULA

Academic Year	1960-1	1961-2	1962-3	1963-4	1964-5	1965-6	1966-7	1967-8[1]
Ph.D. Candidates Enrolled	76	185	284	289	382	463	499	590
Ph.D. Degrees Granted	27	30	27	42	60	61	73	136

[1]Anticipated.

Source: April 1968 Survey by Committee on Marine Research, Education, and Facilities, National Council on Marine Resources and Engineering Development.

between the physical and geophysical oceanographers on the one hand and the marine biology and fisheries oceanographers on the other. There is a growing awareness of these dichotomies. These dichotomies worry scientists as they begin more fully to comprehend the interdependence of their disciplines and realize that the problems of the estuaries, development of marine resources, environmental observation and prediction, can be solved only by concerted effort of interacting disciplines.

If adolescence is measured by excitement and rapid growth, then the present state of marine science qualifies well for this appellation. The new excitement about the oceans has communicated itself quickly. The youth of our country go where the action is and in their mind the action in oceanography is scientifically and intellectually exciting. An ever-increasing number of well qualified students are applying for courses in the marine sciences. Graduate schools in recent years have turned away far more qualified applicants than they have accepted; graduate training today is proceeding at unprecedented levels. Table 8 shows the rapid growth of doctoral candidates and doctoral degrees granted from 1960 to 1968.

The marine science enterprise, in comparison with a decade ago, is healthy, energetic and diversified, with the normal stresses and strains that beset a vigorously growing field.

However, the Nation's current financial stresses are beginning to inhibit growth at a time when the enterprise at the academic institutions is on the verge of full flower.

As a measure of the levelling off of the financial support for marine science the growth in research funds during the past five years of two of the largest agencies which have traditionally supported basic marine science research at academic institutions–the Office of Naval Research and the National Science Foundation–were examined. This growth is shown in Table 9. Since 1963 the rate of growth has decreased from 7.3 per cent to

Table 9. NAVY AND NATIONAL SCIENCE FOUNDATION OCEANOGRAPHIC RESEARCH FUNDING
Total Research Funds
(in millions of dollars)

	Navy CRP[1]	NSF	NSF & Navy	Change
1963	22	13.6	35.6	
1964	24	14.2	38.2	2.6
1965	25.5	15.7	41.2	3.0
1966	26.5	17.3	43.8	2.6
1967	27.0	18.1	45.1	1.3
1968	27.0	19.2	46.2	1.1

[1]Contract Research Program.

2.2 per cent. The amount spent by these two agencies over the years is shown in Figure 2. The period of rapid growth of the first half of the decade of the 60's has stopped.

The momentum attained over the past decade must be maintained for at least as long as necessary to place the activity on a stable, higher plateau that will underpin a total national marine affairs program.

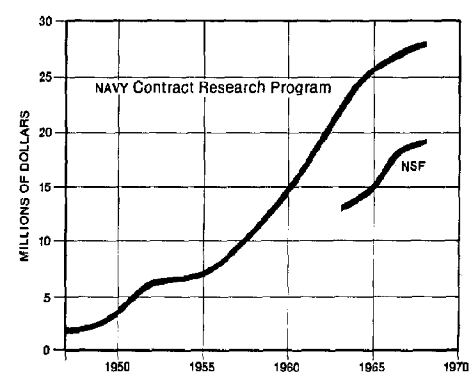

Figure 2. *Navy and National Science Foundation oceanographic research funding.*

The spirit which has carried us to rugged mountain peaks, remote polar ice caps, and distant reaches of outer space now propels us to the ocean deeps. This spirit is fortified with a confidence developed by past contributions of science that we will not only conquer the ocean deeps, but will use them in satisfying the needs of our society.

Hubert H. Humphrey
Vice President

The fundamental challenge and motivation for science is to expand man's understanding of himself and his environment. Society supports the scientist's quest for basic knowledge because its citizens share his curiosity and his faith that this knowledge will yield unforeseen advances in the quality of their lives. Our physical home is a composite of interacting earth, sea, sun and air, and an understanding of the oceans as a major link in the indivisible whole is vital to any real comprehension of the planet.

The oceans represent the dominant feature of our physical environment. They were the cradle of life and their basins were linked, in ways not yet fully understood, to the arrangement of the continents. Many of the world's secrets may therefore be expected to lie locked in or under the oceans.

While studies aimed toward illuminating the fundamental riddles of ocean science have been receiving increased attention and support, the origins of this Nation's interest in the seas have been largely pragmatic, and there continues to be a tendency to require at least a prospect of tangible, economic pay-off from most of the scientific work. This requirement must not be pervasive.

It is our view, and we wish to express it as clearly and forcefully as possible, that understanding our planetary oceans is itself a vital goal of the marine science effort, and one whose cogency is borne out in any historical perspective.

Science born of disinterested intellectual curiosity is not designed for specific gain, but it has produced, with compelling regularity, applications which have literally changed the face of the earth. Man tried to know and measure the nature of the stars and the planets long before mariners used them to navigate by. Knowledge of the relief of the deep ocean bottom, at first pursued for purely scientific reasons, was soon sought for practical applications such as trans-ocean telegraph cables.

We see clearly the necessity for attacking the problems of resource management and development, of environmental prediction, or those associated with National security, but only dimly the need for the knowledge to come from the pursuit of our intellectual curiosity. In fact, the temptation to concentrate on the solutions to specific, near-term problems is almost overwhelming.

A program of basic marine science directed toward the understanding of our whole planet must be regarded as a National investment of our scientific and intellectual resources with utility above and beyond its immediate return. It must also be regarded as the sound way to guarantee that the United States has, at all times, a pool of talented and knowledgeable manpower upon which to draw in hours of danger to our physical or economic health, or our National security.

The oceans have traditionally been a highway of commerce, a source of nutrition, and an area of struggle. In the future, use of the oceans as a source of raw material will increase, marine foods will play an increasing role in nutrition, and it seems certain that the oceans will remain an area of power struggle. The nation must maintain its reserves of marine scientists and marine expertise at a level equal to the many problems likely to face us, as the seas become more important to all of the nations of the world. With increasing frequency, crisis situations require the trained marine specialist, as, for example, the search for the submarine *Thresher,* the search for the nuclear bomb off Spain, and the cleanup of the *Torrey Canyon* oil spill.

How should the marine science community organize for its share of the total task of planetary understanding?

In the light of our traditions, of the nature of the scientists, and of our National history of scientific achievement through freedom of inquiry, it is clear that regimentation is not the answer. Scientific activity gravitates quite naturally to the

SEAMOUNT OR GUYOT. IT IS APPROXIMATELY 9 MILES WIDE AT ITS CREST AND RISES 9,000 FT. ABOUT THE SURROUNDING OCEAN FLOOR. A THIN VENEER OF SEDIMENTS OVERLIES THE IGNEOUS CORE.

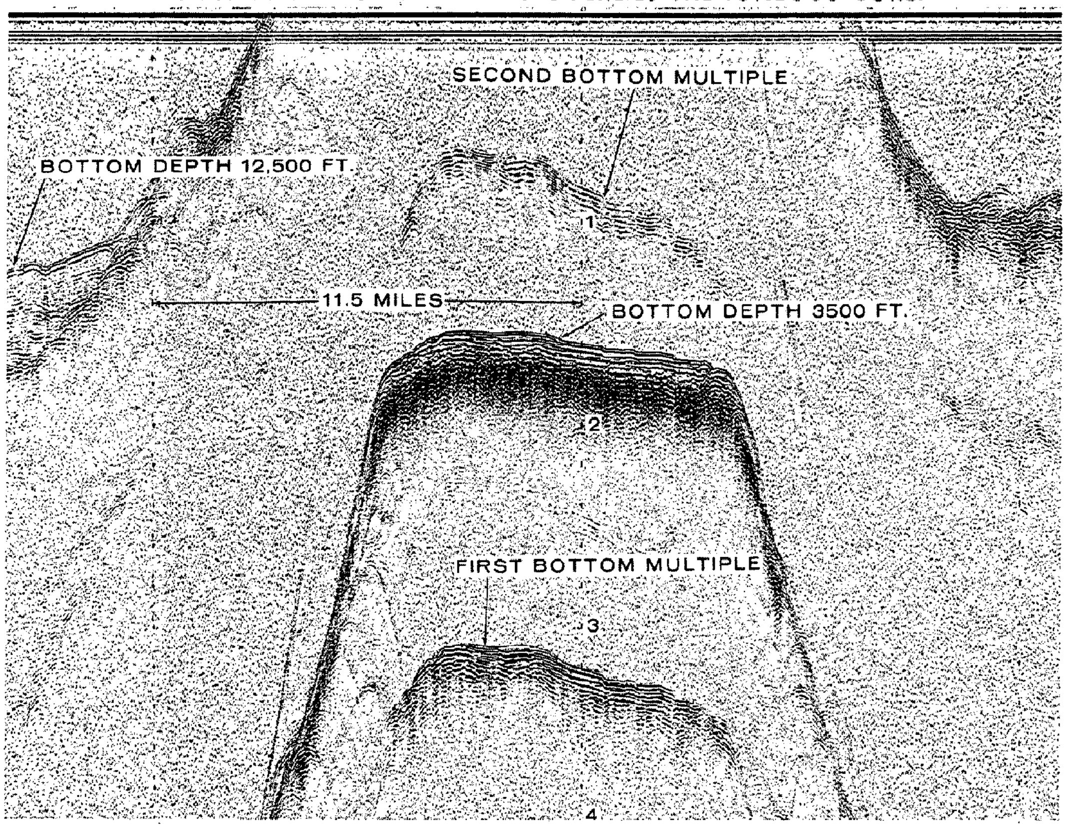

Figure 3. *(National Science Foundation photo)*

areas of greatest challenge and need. It should be our inclination to support the scientist interested in the basic problems of understanding the planetary oceans and to provide the institutional, facility, and Federal support necessary to his work.

What are some of the problems that our scientists find ripe for study? The nature of the earth's evolution is not understood, nor why the continents have their shapes and locations, nor why the sea floor is rugged with ridges, seamounts, and trenches. Scientists now believe that, given an adequate quantity and quality of observations, an explanation of these fascinating questions may be near. In studying them, a store of information about the sea floor and its composition can be acquired for a multitude of uses which today cannot be foreseen.

Scientists are coming increasingly to believe that our continents have drifted to their present locations in response to the dynamic currents of the earth's core, that the ocean ridge system is an integral part of this process.

The theory of continental drift was set forth clearly by the meteorologist Alfred Wegener in 1912.[1] It remained largely uncredited in the United States until the 1960's because nobody could account for any energy source capable of moving masses as large as continents. Now, largely due to the work of geophysicists and geochemists in the ocean and on the continents, a composite portrait has begun to emerge, based upon systematic measurements of the thicknesses of ocean sediments, the magnetic properties of ocean volcanic rocks, the geo-chronology of continental rocks, the heat flow through the ocean floor.[2]

The case has yet to be proven and the details of the mechanics yet to be understood. Scientists

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[1] *Die Enstehung der Kontinente,* Wegener, Petermann's Mitt. 58, 1912.

[2] *Spreading of the Ocean Floor: New Evidence,* Vine, Science, Vol. 154, No. 3755, Dec. 16, 1966.

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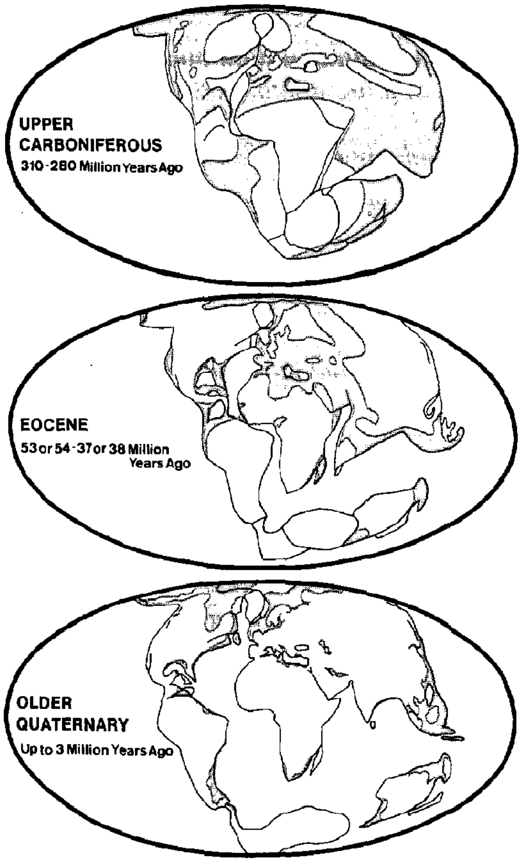

Figure 4. *A. Wegener's depiction of continental drift for three geologic periods. Shaded area is ocean; dotted areas are shallow seas. Present-day outlines and rivers are shown only for purposes of identification. (A. Wegener,* The Origins of Continents and Oceans, *trans. from the third German edition, 1922)*

know what must be measured and where. One of the fundamental puzzles of the planet appears soluble.

Much has been learned about the living creatures of the ocean; comprehension of the dynamics of the food web of the seas is beginning, but many blind spots remain. Scientists are puzzled about life in the deepest parts of the ocean. They ask: how do animals living more than 2,000 meters under the sea sustain themselves? The biomass there is only a miniscule fraction of that in the shallow, illuminated layers where the world's fish are harvested. There may well be no fish crops worth seeking at those depths. Yet, about 84 per cent of the ocean floor lies below 2,000 meters, and a large part of the total nutrients in the ocean cycle through this zone. The

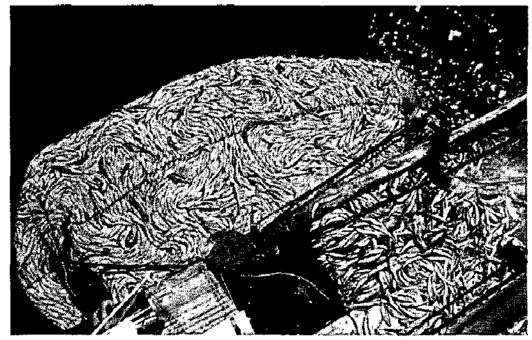

Figure 5. *Twenty tons of Pacific hake* (Merluccius productus) *caught by Bureau of Commercial Fisheries research vessel* John N. Cobb *in a one-hour midwater trawl. (Bureau of Commercial Fisheries photo)*

temperature is stable and cold; the tempo of life, a crawl. There are no photosynthetic plants. The supply of energy into the food web comes from above. There is virtually no information on the rate at which organic matter is delivered, or its division for consumption among bacteria, bottom-living animals or fish. If use of the deep ocean is anticipated, it is necessary to build our understanding of the fundamental processes which occur there. Will they be used for the disposition of radioactive and human wastes? Will man be working and operating at such depths? At great depths, plants and animals selectively concentrate radioactive isotopes, they become food for other animals which may go higher and in turn become food for commercial fish. The meager store of knowledge of this portion of the food web must be materially increased. The capability to study in these depths must be developed.

Much has been learned of the chemistry of the oceans, but major mysteries remain.

The ocean is a 3.5 per cent salt solution containing all the known naturally occurring elements. The major components and some of the minor ones are present in constant proportions throughout the world ocean. Despite the variable composition of streams feeding the ocean, the constancy is maintained by chemical reactions in the sea, both as the result of biological activity and interaction with detrital material. These processes have not yet been fully understood, although well thought-out models have been proposed. Some of the trace elements, including a few that are clearly fundamental to life processes, show variation with depth and geography. The significance of these variations to large-scale processes in the ocean, such as ocean circulation, biological productivity, and sedimentation, have been guessed at but still remain obscure. When will such knowledge be required?

Other classes of chemical species that have been studied in the last decade are the stable and radioactive isotopes. The differences in the abundances of the hydrogen and oxygen isotopes in the ocean can be related to formation of water types and oceanic circulation. Radioactivity can be used to study oceanic processes because of its clocklike nature.

Numerous radioactive isotopes, both naturally produced or man-made, have been used to elucidate the mechanisms of ocean water movement, both in surface and deep waters, and the kinetics of air-sea interaction. Scientists believe the pursuit of such studies will teach more about the nature of the oceans as a fluid. The applications of such studies cannot be foreseen today; but no one doubts that there will be applications.

And what can the oceans tell us of climate? Scientists today appreciate the profound influence of the oceans upon the climates of the world; they are just beginning to understand the coupling between the oceans and the atmosphere, but they do not fully understand how the influences are propagated. A sound theory of climate would account for ice ages of the past and possibly of the future.

A complete understanding of the ocean must include the study of the remains which previous civilizations have left us in the sea. New technology holds great promise for more efficient underwater search: side scanning sonar, metal detectors, and improved seismic and three dimensional mapping techniques are already in use and are being improved.

If oceanography is the study of the sea in all its aspects, then marine archeology, being the physical record of man and the sea, must be an essential part of the discipline and should have visibility in any comprehensive program.

These questions—and others could as well be propounded—go to the heart of our comprehension of the origin, dynamics, and changes in planet Earth. The search for answers will be difficult, but it will have lasting consequence for the Nation and all humanity. It is a challenge that must be met with a vigorous National program.

"To probe the mysteries of the sea" was identified by President Johnson as the first goal of his proposal for an International Decade of Ocean Exploration. Since science is inherently an international concern and the planetary oceans affect and interest us all, it is appropriate that advances in understanding the fundamental characteristics of the ocean environment should be achieved as a cooperative, international effort. The proposed Decade is one mechanism by which a fruitful program can be organized to achieve this.[3]

Recommendation:

The Nation should establish as a major goal the advancement of an understanding of the planetary oceans as a principal focus for its basic marine science effort. The proposal by President Johnson for an International Decade of Ocean Exploration is an excellent concept through which this major goal can be achieved.

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[3] *International Decade of Ocean Exploration,* Report by the National Council on Marine Resources and Engineering Development, 1968.

We are just at the threshold of our knowledge of the oceans. Already their military importance, their potential use for weather predictions, for food and for minerals are evident. Further research will undoubtedly disclose additional uses.

Knowledge of the oceans is more than a matter of curiosity, our very survival may hinge upon it.

Basic research is the cornerstone on which the successful use of the seas must rest.

John F. Kennedy
March 29, 1961

In approaching its task of defining the role of basic science in the National marine effort, the Panel was confronted with the question: Basic science for what purpose?

A certain amount of effort must be devoted to the understanding of the processes of the oceans if only to insure the availability of knowledge about one of the most important areas of National activity.

An equally pressing and more immediate need quickly became apparent: the realization that the principal programs advocated by the Commission as the very core of the Nation's thrust into the sea would be seriously impeded—and in some cases so limited as to be defeated—by ignorance of specific types of basic oceanic processes. In many parts of these programs, acquiring this fundamental knowledge represents the only hope of success.

The programs advocated by the Commission go to the heart of important segments of National life. Among them are plans for dealing with the management and development of our estuaries, coastal waters, and Great Lakes, of our living and mineral resources, for the use of the seas for National security and the monitoring and prediction of the ocean environment.

A determination was sought as to how the programs were limited by scientific knowledge, and to attempt to make the Nation aware of those areas which need radical acceleration.

I. BASIC SCIENCE AND THE NEAR SHORE WATERS

The effective use of coastal and estuarine zones and the Great Lakes is among the most urgent marine problems facing the Nation. The Commission calls for the institution of an improved system for the rational management of these vital areas.

Near shore waters and the Great Lakes and their adjacent waterfront lands are some of the most valuable in the Nation. They have a great variety of uses: transportation, shoreline development, recreation, the recovery and exploitation of living and mineral resources, National defense, wildlife preservation, and waste disposal.

The Panel Report on Management and Development of the Coastal Zone investigates in detail the problems arising from the many uses of these zones.

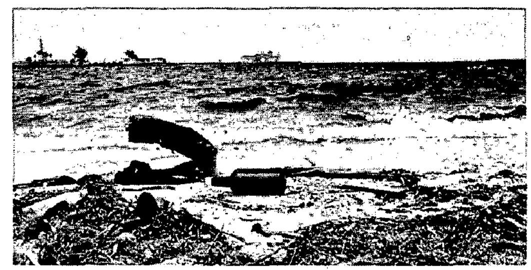

Figure 6. *Degradation of shore area due to uncontrolled pollution, Pinellas County, Florida. (Federal Water Pollution Control Administration photo)*

From the viewpoint of basic science, the conflicts among uses and users of these areas are many and of increasing severity. One cannot expect to dredge gravel from the right-of-way of a submarine pipeline, to plant stakes for a fish trap in a shipping lane, or to water ski in a gunnery range. Adjudicating conflicting claims to the uses of these valuable areas is difficult at best, but a prerequisite for any rational use is an understanding of the consequences of one use on others. In many cases the necessary knowledge is not available. It is here, in the management of these zones, that the greatest urgency for action in the face of insufficient knowledge appears.

A. Changing the Shape of the Coast

Man's technology has given him the power to reshape his coasts, and he has used it extensively and, for the most part, well. The record of the past, however, will not satisfy the needs of the future. Natural land and seascapes, the wetlands that serve as breeding grounds for fish, and the beaches are being eroded both by nature and man. It is necessary to predict more precisely the consequences of nature's actions and man's; to do this, substantial strides in basic science are required.

Keeping coasts and harbors in repair and developing them is an unending challenge. Approximately two-thirds of our coastline is considered poorly protected or endangered,[1] despite the fact that the Nation has invested substantial sums of money in their upkeep.

The Corps of Engineers has developed 500 commercial harbors with depths up to 45 feet, 250 for small craft, and has improved 23,000 miles of intracoastal and inland waterways. Since 1946, the Corps has undertaken more than 100 projects

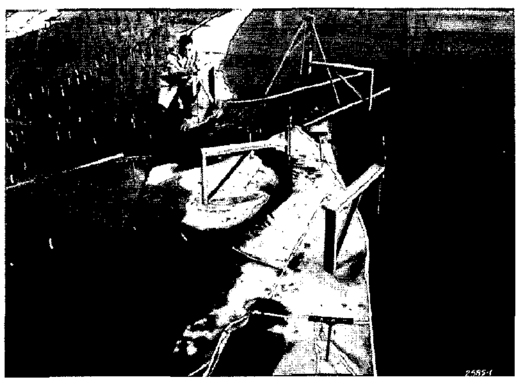

Figure 7. *Texas coast hurricane surge model. Hydraulic model constructed to a scale of 1:100 vertically and 1:3,000 horizontally is being used to determine the most suitable plan for hurricane surge protection for the Texas coast. Tides and tidal currents are reproduced in model by tide generator located in Gulf of Mexico portion of model. Hurricane surges are reproduced by horizontal displacement surge generator. (Army Corps of Engineers photo)*

designed to stop beach erosion at a total cost of $237 million, of which the Federal share was $94 million. As severe storms battered our shores, $361 million–$253 million of it Federal funds–have been invested in hurricane protection under Corps of Engineers direction since 1958.[2]

[1] *Annual Report of the Corps of Engineers,* Vol. II, 1966.

[2] From information furnished the panel by Brigadier General H. G. Woodbury, Jr., Director of Civil Works, Office of the Chief of Engineers, Oct. 9, 1967.

Tables 10 and 11 show the level of Federal effort in the estuaries and Great Lakes.

Table 10. ESTUARIES
(in millions of dollars)

	Estimated FY 1967	Estimated FY 1968
Smithsonian Institution . .	1	1
Department of Commerce .	2.0	0.6
Atomic Energy Commission	0.3	0.3
Department of Transportation	1	1
National Science Foundation	0.5	0.6
Department of Health, Education, & Welfare[2] . .	3.5	1.4
Department of the Interior	19.9	23.4
1. Bureau of Commercial Fisheries	(8.5)	(9.3)
2. Geological Survey	(1.1)	(1.2)
3. Bureau of Sport Fisheries	(4.3)	(5.1)
4. Federal Water Pollution Control Administration	(3.8)	(5.0)
5. Office of Saline Water .	(0.8)	(1.0)
6. National Park Service .	(1.4)	(1.8)
Department of Defense . .	3.9	4.5
1. Department of the Army	(1.9)	(2.2)
2. Department of the Navy	(2.1)	(2.2)
Total	26.6	29.4

[1] Less than $50,000.

[2] Includes $2.1 million in construction in FY 1967.

Source: *Marine Science Affairs,* 1968.

Much more needs to be known about the physical processes that shape our coastlines and estuaries: how, for instance, combinations of waves, tides, and currents affect depositon and erosion; the sources of beach sands, and when and how it is naturally removed from beaches; and the effects of storm surges.

Simulation of observed conditions through the construction of hydraulic scale models and mathematical models will improve predictions of the effects of change.

More needs to be known of the marine organisms and biological processes of the coastal zones. Detailed information on the food web, tolerances of each species to environmental change, and the

Table 11. GREAT LAKES
(in millions of dollars)

	Estimated FY 1967	Estimated FY 1968
Department of Commerce .	0.1	0.1
Department of Transportation	0.0	0.0
State Department . . .	1.0	1.0
National Science Foundation	.2	.2
Department of Interior . .	3.3	2.9
1. Bureau of Comm. Fisheries	(1.5)	(1.8)
2. Bureau of Sport Fisheries	(0.3)	(0.3)
3. National Park Service	1	(0.1)
4. Federal Water Pollution Control Administration	(1.5)	(0.7)
Department of Defense . .	2.5	3.6
1. Department of the Army	(2.4)	(3.5)
2. Department of the Navy	(0.1)	(0.1)
Total	7.1	7.8

[1] Less than $50,000.

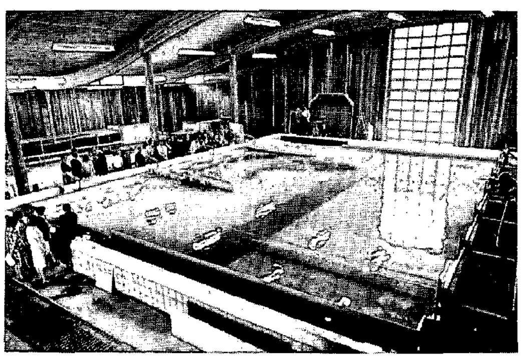

Figure 8. *Scripps oceanographic model tank for simulating waves and other ocean phenomena is an example of the unique laboratory facilities required for oceanographic research. (University of California photo)*

distribution and abundance of organisms must be obtained to make the most effective use of this rich region.

Lack of basic understanding prevents the effective use of near shore waters. On the one hand, the ill effects of our actions cannot be foreseen in time to correct them; on the other, when irreversible harm might occur, we do not know how to prescribe the right amount of corrective action and are forced to base regulations on the most conservative estimate of probabilities. The solution of engineering problems suffers from the lack of knowledge of the dynamics of inshore water movements. There is no theory suitable to describe the turbulent motion of water particles in the surf zone, nor can our instruments accurately measure currents in this area.

In the process of altering our land and water for beneficial purposes, man frequently produces catastrophic side effects. Dredging is carried on for a variety of reasons:

–Creation and maintenance of navigable channels and inlets for commercial and recreational use;

–Creation of useful property, marinas, recreational areas;

–Improved flushing action in bays, and estuarine creeks;

–Commercial mining of sand and gravel.

It is not only what is done along the shores that affects coasts and beaches, action far upstream may have drastic consequences. The flushing of minor embayments within estuaries is heavily influenced by seasonal fluctuations in salinity, largely through natural changes in river flow. Regulation and evening-off of river flow may prevent flushing action and allow a buildup of predators which rob shellfish beds of much of their richness. Basic research in microscale estuarine circulation must continue if predictions of the effects of our actions in regulating the flow of rivers are to be made.

A classic example of side effect has been the invasion by the lamprey eel[3] when the upper Great Lakes were opened to the sea possibly as early as the opening of the first Welland Canal, in 1833, and certainly by the time of the deepest (and fourth) canal in 1932. The eel brought a cycle of biological change which has already destroyed most of the lake trout. Immigration of alewives into Lakes Erie and Michigan and their large populations has resulted in the shores of Lake Michigan being littered with millions of dead alewives. Furthermore, a new ecological balance has yet to be reached.

[3] *The Spread of the Sea Lamprey Through the Great Lakes,* Hubbs and Pope, Transactions of the American Fisheries Society, 66, 1937.

Knowledge resulting from research has, on repeated occasions over the years, eased strains between fishermen and companies exploring for oil reserves off the Gulf and West Coasts.

The geophysical surveys needed to evaluate the oil-bearing potential of an area involve the use of explosives. Fishermen, fearing massive fish kills, have protested vigorously when surveys were imminent. Extensive research to determine where the damage threshold lay showed the lack of danger to the fishing interests, by the use of animal cages recovered after demonstration shots. Explosions were also timed not to interefere with fish migrations. The balance between the needs of the geophysicist and the safety of marine populations was preserved.

In light of the large investment made by Federal, State, and local governments to shape our coastlines and estuaries to our needs, the present effort devoted to acquiring the fundamental knowledge of near shore and estuarine processes is inadequate.

Recommendation:

Each Federal agency concerned with near shore waters should devote a considerably higher per cent of its funds to basic research in the physical processes which shape our coastlines and estuaries. This will insure the availability of essential knowledge necessary to plan and implement programs for their protection and preservation.

B. Polluting the Waters

Man has brought profound upheaval in the natural balance of our environmental forces, an upheaval which perils his own well-being today, and which, unless current trends are reversed, will pose even greater danger tomorrow.

Usually, these disturbances are the result of gradual accumulation or modification—the building of cities, clearing of forests, plowing of prairies, leveling of dunes, the addition of flush toilets, the use of leaded gasoline or agricultural chemicals, and disposal of industrial wastes. They can consist of dissolved, suspended, or floating material. They can be thermal, by augmentation of the heat content of the water mass through its use as a cooling liquid. Or they can result not from artificial additions to the environment but from artificial subtractions; the diversion of fresh water can lead to increased salinity in an estuary, with resulting changes in the biota.

Normally such environmental changes are gradual and reversible by ceasing the activities that generated them. The estuaries and the Great Lakes where the drainage of the land is finally delivered are seriously affected by waterborne pollution.

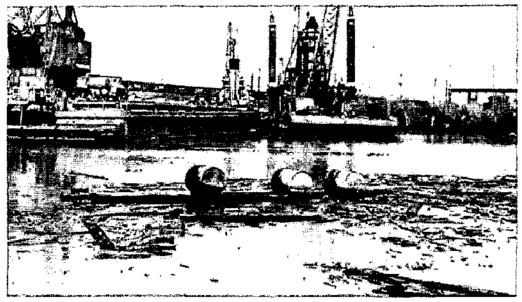

Figure 9. *Assorted debris, including a floating dock, polluting Cuyahoga River, near Cleveland. (Federal Water Pollution Control Administration photo)*

Attack on the problems of pollution must be accompanied by an increased level of basic research on the dynamics of estuarine waters, on the identification of specific pollutants and the tracing of their effects, both on individual species and on ecosystems, and on the mechanisms whereby organisms in the estuarine ecosystem take up and accumulate various kinds of pollutants.

Numerous examples can be cited where the lack of basic knowledge has created intolerable conditions. The introduction of modern agricultural chemicals has created problems in our estuaries and Great Lakes.[4] Runoff of excess fertilizers contributes an over-supply of nutrients; runoff of herbicides and pesticides is toxic to marine organisms. Even when the level of concentration in the water is low, the pesticide can be successively concentrated as it moves through the food web.

The fact that, unlike municipal and industrial pollutants, agricultural pollutants do not originate at a point source adds to the complexity of the problem.

The problem of marine pollution cannot be solved in isolation from the more general problem of wider waste management and control. A particularly comprehensive document in this regard is the National Academy of Sciences' study, "Waste

[4] *Great Lakes Restoration—Review of Potentials and Recommendations for Implementation,* Research Report to the Commission by Pacific Northwest Laboratories of the Battelle Memorial Institute, June 1968.

Management and Control,"[5] which points to the need for consideration of the total problem and all the possible alternatives offered.

Whatever ultimate solutions are proposed for the nation to combat the entire spectrum of environmental pollution, key elements of knowledge must be available on the processes in our estuarine and near shore environments.

Recommendation:

The Nation should undertake a much enhanced program of basic research into the dynamics of estuarine waters, the identification of specific pollutants and the tracing of their effects, both on individual species and ecosystems, and on the mechanisms through which organisms in the estuarine ecosystem take up and accumulate various kinds of pollutants.

C. Fish Habitats

As pointed out in "Changing the Shape of the Coast" and "Polluting the Waters," one of the principal uses of the near shore environment which conflicts violently with other uses is the harvest and natural breeding ground of some of the most valuable shellfish and finfish. Table 12 lists the large number of sport and commercial species of Atlantic finfish which are estuarine dependent.[6] In addition, the very valuable shrimp and shellfish industry is estuarine dependent.

The conservation and management of our fisheries is vitally dependent upon our knowledge of these regions as habitats. The relationship of the biota to physical changes in their estuarine environment constitutes a major problem. The overlapping, often contradictory needs of this population require careful research on the habitat preferences of each species or ecosystem under consideration. Natural disturbances often have catastrophic effects upon marine populations. Mass mortalities often result from sudden changes in salinity, temperature or the depletion of oxygen.

Further, the changes likely to be wrought by such engineering activities as constructing drainage systems, dredging channels and disposing of spoil, building seawalls and jetties and stabilizing dunes, all require investigation.

On the other hand, modification by man to alleviate environmental stress, while impractical in the open ocean, can be accomplished in the more limited confines of the estuary. Thermal changes resulting from the operation of power plants or desalination facilities may be used beneficially; breakwater construction, creation of artificial reefs, dredging operations and river flow control all may serve to enhance and augment the estuarine and near shore habitat.

Such information as the Nation needs cannot be obtained over the short term. If we are to

[5] *Waste Management and Control,* National Academy of Sciences-National Research Council, Pub. No. 1400, 1966.

[6] American Littoral Society, Spec. Pub. No. 5, 1967.

Table 12. IMPORTANT ESTUARINE-DEPENDENT ATLANTIC GAME AND COMMERCIAL FISH[1]

Adults found mostly in the estuaries, some only seasonally	Adults found partially in the estuaries, some only seasonally	Adults found mostly along the open coast
Flounder (winter flounder or blackback)	Striped bass (rockfish)[2]	Bluefish
Spotted trout	Fluke (summer flounder)	Tautog (blackfish)
Tarpon	Porgy (scup)	King whiting (kingfish)
Croaker (hardhead)	Weakfish (squeteague or white trout)	Alewife (river herring)[2]
Snook	Red drum (redfish or channel bass)	Shad[2]
Spot (lafayette)	Black drum	Atlantic mackerel
White perch[2]	Mullet	Menhaden (bunker pogy)
		Black sea bass

[1] The three categories represent a rough approximation of habitat preference of adult fish.

[2] Anadromous species: Living as adults in salt or brackish water but spawning in fresh or nearly fresh water.

Source: *Fish and Man,* American Littoral Society, Spec. Pub. No. 5, 1967.

understand the effects of change upon fish habitats, we need natural laboratories in which we can study the rhythms and relationships governing the physical and biological environment of the estuarine zones, over a period of time.

Untouched estuarine and near-coastal zones are rapidly disappearing. It is urgent that the Nation set aside and preserve a sufficient number of such estuaries to provide the natural laboratories required to generate the information and understanding that will increasingly be needed. This information will have predictive value essential to evaluation of the possible effects of planned environmental changes and will also provide insight for the correction of existing adverse conditions.

The National Academy of Sciences Committee on Oceanography recommended the establishment of large scale laboratory facilities for study of the survival requirements of young fish and shellfish.[7] In a letter to the panel, the Committee reviewed its previous recommendation and reiterated its view.

Unspoiled study areas must be set aside for permanent scientific use. As many as five such preserves will be required: one in the cool water regions and one in the warm water regions of both East and West Coasts and one on the Gulf Coast.

Recommendation:

Specific representative sites should be selected for careful, prolonged study to permit the accumulation of basic knowledge essential for understanding the statics and dynamics of the coastal regime.

II. DEVELOPMENT OF LIVING RESOURCES

The living resources of the sea have historically been a staple of man's diet. Today, the technology of catching and marketing fish has revolutionized the ways in which the riches of the sea are harvested.

The National policy implications for, and the role of United States fisheries in the context of these rapidly-changing conditions are treated extensively in the report of the Panel on Marine Resources. This panel, therefore, has sought to learn whether basic science problems exist which are critical to the expansion of our national fisheries.

It is generally admitted that providing food for a burgeoning population is one of the most critical problems facing mankind over the next 20 years. The quality and very existence of human life for millions of persons depend upon its success, and man must turn to the oceans for part of the answer to this vital question.

The report of the Panel on the World Food Supply of the President's Science Advisory Committee listed as its first basic conclusion:[8]

The scale, severity, and duration of the world food problem are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it.

Fish is consumed in a number of ways: indirectly in enormous quantities, both in the United States and abroad, through the medium of fish meal used in the production of poultry and pork; and directly, as a source of protein. Although it does not appear that the sea can supply the needed increase in carbohydrates, food from the sea can help supply the badly needed increased amount of protein. Among the sources of food additives now being developed are leaf and oil protein, fish protein concentrate, and cultured marine algae. Presently, the animal protein additives contain the largest number of badly needed essential amino acids.

Fish protein concentrate production has begun but there are numerous problems to be solved in adapting the process to other species. Further, if it is to be used in the tropics, the technology must be developed for making FPC from multiple-species catches.

For all these reasons, the problem of insuring adequate supplies of raw fish is of critical concern, especially in the face of fish stocks which are finite in size.

A. Fisheries—Traditional and New

Efficient management of traditional fisheries depends upon the Nation's adding to its basic understanding. Particularly needed is an under-

[7] *Oceanography 1966*, National Academy of Sciences, National Research Council, Pub. No. 1492, 1967.

[8] *The World Food Problem*, Report of the President's Science Advisory Committee, 1967.

standing of the relationships between environmental conditions and infancy and egg survival for many of the stocks.

Science must come to understand the interaction of competitor-predator systems, the study of the dynamics of multi-species systems under predation. For example, the replacement of the commercially important Pacific sardine by the less valuable anchovy was apparently the combined result of a highly selective fishery and natural environmental change, the interactions of which are not understood.[9]

Better correlations between environmental conditions and fish abundance, when accompanied by better monitoring and prediction of those conditions, should enable fishermen to work more productively and efficiently.

Figure 10. *Global scientific expedition 1967. Modern oceanographic observations are utilizing complex electronic instruments such as this salinity-temperature-depth sensor. Although more costly than classical instruments, these instruments portray more accuracy and realistic measurement of the actual ocean structure. (ESSA photo)*

"New fisheries" are defined as those involving the harvesting either of species previously not exploited or of previously untouched stocks of species that are fished elsewhere. The most urgent requirement for scientific information in the case of a new fishery is for rapid means of stock assessment. There must be determinations of abundance, susceptibility to existing fishing techniques, and, for effective continued use, maximum sustained yield. Exploratory fishing may reveal potentially exploitable stocks, but basic studies in population dynamics are necessary to evaluate the long term value of a new fishery. Many experts believe the harvest of currently-exploited ocean fish can be quadrupled.[10] If the present 7.7 per cent annual rate of increase of world landings, which has been maintained for more than a decade, continues this level will be reached in 20 years, when many more stocks than at present will be exploited at near-maximum yields.

There is, thus, an urgent need for the development of methods for fishery resource management, based on such modern technology as computer simulation models which will take into account, for each stock of fish, not only natural rates of reproduction and growth, food abundance, natural mortality, and the increased mortality caused by fishing, but also such economic factors as the operational effectiveness of different types of gear and processing and marketing costs. The fashioning of such models will require basic research, since simulation models are no better than our understanding of the interactions between the processes they simulate.

The use of an approach which fully considers the interactions among the marine organisms, their environment and modern technology, is essential for effective fisheries management.

Recommendation:

A continued and expanded effort be directed toward achieving a basic understanding of such key problems as fish population dynamics, the effect of environmental conditions on fish population, and the dynamics of multi-species systems under predation.

[9] *Population Biology of Pacific Sardine (Sardinops caerulea),* Murphy, Proceedings of the California Academy of Sciences, fourth series, Vol. 34, No. 1, July 1966; numerous publications of the California Cooperative Fishery Investigations (Cal. COFI).

[10] *The Potential Harvest of the Sea,* M. B. Schaefer. Transactions, American Fisheries Society, Vol. 94, No. 2, April 1965.

B. Aquaculture

An entirely different set of requirements for basic research exists in aquaculture, the husbandry of aquatic organisms. Progress has been severely limited by lack of information on the genetics and breeding of potentially valuable species, the food requirements of the juvenile organisms at various stages, the nature and treatment of disease, and optimum environmental conditions at different stages of growth.

Although marine aquaculture holds limited promise for direct production of cheap protein food in the foreseeable future, the potential is high for food production through controlled feeding and selective breeding, and even for manipulation of the genetic makeup of marine species in culture.[11]

Great success in culturing fresh-water species has been attained in many parts of the world.

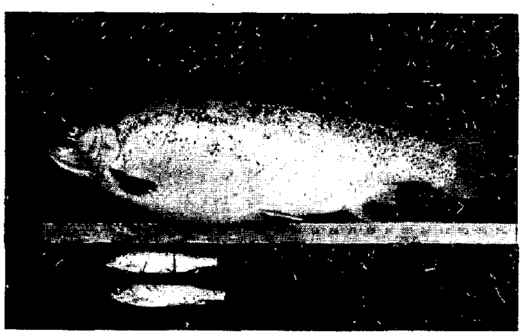

Figure 11. *The advantage of scientific fish breeding is vividly shown by results obtained by Professor Lauren Donaldson of the University of Washington. The small fish are two-year-old wild stock rainbow trout. The large fish is of the same stock and age but is the product of many years of selective breeding. (Photo by Professor Donaldson)*

Israel, for example, obtains from 40 to 50 percent of its fish from pond cultures.[12] Estimates for *1960* from mainland China show annual fresh water fish landings at four million tons, half of which came from fish culture.[13] During the same year, the total landings in the United States of all fish and shell fish destined for human consumption was under 1.3 million tons.[14]

Recent reports on the Columbia River hatchery program of the Bureau of Commercial Fisheries show the potential of this aspect of aquaculture. It is estimated that the Columbia River system contributed 28 million pounds of salmon to the 1967 catch, an estimated 15 million pounds of which were from the hatchery operation. Cost benefit analyses show a ratio ranging from 2.5:1 to 4.5:1 for fall chinook runs and a high of 7.8:1 for coho. The figures are based mainly on the ex-vessel price of the commercial catch.

BCF estimates that the hatcheries now operate at 65-85 per cent of capacity, and that with full capacity operation, plus modest investments in such equipment as automatic feeding devices, the hatchery contribution to the fishery could be doubled. Better understanding of selective breeding and optimum nutritional requirements of the young could bring production up to 50 million pounds per year.[15]

The farming of species spending all or part of their lives in salt water has been drastically limited by a lack of basic information. Only luxury species such as shrimp and oysters have been commercially cultured, but there are many encouraging indications in the field. Research at the University of Washington on salmonoid fishes has demonstrated the possibility of hundredfold increases in the size of cultured fish versus wild fish of the same species and age.[16] The short generation time and high fertility of most marine organisms make them good subjects for selective breeding. Just as we now breed hornless, short-legged beef that could not compete in nature, so the protection of cultured marine organisms against their natural predators will permit selective breeding for characteristics useful to man.

It is important to establish viable aquaculture systems and there is sufficiently great long-term promise to warrant the following recommendation.

[11] *The Status and Potential of Aquaculture,* Ryther and Bardach, Report to the National Council on Marine Resources and Engineering Development by the American Institute of Biological Sciences, 1968, Clearinghouse for Federal Scientific and Technical Information, Pub. No. PB 177 768.

[12] Bamidgeh, *Bulletin of Fish Culture of Israel,* 19(2/3) June 1967.

[13] *Economic Aspects of the Fishing Industry in Mainland China,* Solecki, University of British Columbia, 1966.

[14] *Marine Science Affairs,* 1968.

[15] These data were provided by the hatchery evaluation program of Bureau of Commercial Fisheries.

[16] *Selective Breeding of Salmonoid Fishes,* Donaldson, Conference on Marine Aquaculture, Oregon State University, Marine Science Center, May 1968 (in press).

Recommendation:

Major new efforts directed toward the understanding of the reproduction, growth, and development of potentially exploitable marine organisms should be undertaken to provide the base of understanding and technology necessary to make the products of aquaculture more available.

III. DEVELOPMENT OF MINERAL RESOURCES

The panel, mindful of the report of the Resources Panel, here confines its discussions to those aspects of resource development which are limited by the lack of fundamental knowledge. The Resources Panel has pointed out the growing contribution to the Nation's needs for oil and gas and sulphur which are being made by offshore deposits, both along our own shoreline and the shorelines of other nations. It points to the need to start now to explore the potential of our continental shelves for the contributions to the Nation's future needs for hard mineral resources.

Mineral resource development is not presently limited by a lack of basic understanding of mineral formation processes in the sea any more than on land. The principal limitations are in technology, exploration, and economics. The basic nature of the processes leading to mineral deposit and oil accumulation appear adequately understood to the point where they concern location and exploitation of mineral resources under the sea. Further exploitation of these resources depends to a great degree upon the preparation of a complete inventory. The needs are for topographic, geophysical, and geologic mapping and charting. There is need for elucidating and portraying the details of the geological structure on the Continental Shelf and slope; the structure of these margins is incompletely understood.

Except for the hot brines and their associated deposits in the Red Sea, the materials of potential economic importance presently known to exist on the deep ocean floors beyond the continental slope are the ferro-manganese nodules and crusts.[17] They also contain small percentages of copper, cobalt, and nickel, and these metals appear to be of greater potential value than the dominant manganese or iron with which they are associated. The mechanism of formation of these deposits is obscure, and nothing is known about the processes that determine their content of copper, cobalt or nickel.

Because of the mineralogical dissimilarity to ores now being exploited on land, research on procedures for separating the metals in these nodules is required.

Although hot brines like those of the Red Sea and the deposits associated with them have not been found in other regions of the ocean, the possibility that similar formations may exist in other regions of the mid-ocean ridge systems should not be overlooked.[18] Further studies of the elements and isotopes contained in the brine pools and their underlying sediments should be made for clues about their age and origin, a procedure which may facilitate the search for such deposits elsewhere in the ocean.

The panel has recommended a much enhanced program of basic science directed at understanding our planet through research on the geology and geophysics of the ocean floor. (See "Basic Science–Key to Understanding Our Planet.") It feels that this effort will satisfy the basic science needs for the mineral resource development.

As we have indicated, we support the objectives of the International Decade of Exploration[19] proposed by the United States. These objectives include:

Determination of the geological structure and mineral and energy resource potential of the world's continental margins.

Preparation of topographic, geological, and geophysical maps of selected areas of the deep ocean floor.

Coring and drilling on the continental margins and deep ocean floor in selected areas. . . .

Investigations of evolutionary processes of ocean basins.

[17] *The Mineral Resources of the Sea,* Mero, American Elsevier Publishing Co., 1965.

[18] *Hydrographic Observations of the Red Sea Brines,* Munns, Stanly, Densmore, Nature, Vol. 214, No. 5093, 1967.

[19] *International Decade of Ocean Exploration,* Report by the National Council on Marine Resources and Engineering Development, May 1968.

Recommendation:

The basic science effort required to achieve the understanding of the planet (see Basic Science–Key to Understanding Our Planet) should be supported as a necessary National effort to provide the basic geological and geophysical knowledge of the oceans required for the National program of marine mineral resource development.

IV. ENVIRONMENTAL MONITORING AND PREDICTION

All groups using the oceans have a commonality of needs for ocean and weather observations and predictions. One would be hard put to identify any marine activity not dependent upon such services, or whose operations could not be safer and more efficient if those services were improved. National defense, marine transportation, offshore gas, oil and mineral industries, fisheries, waste management, the protection of life and property along the shoreline, recreation–all have a vital stake in it. The need for an environmental observation and prediction system, in fact, goes far beyond marine interests, since the oceans are a major determinant of the weather. Monitoring the marine environment involves the measurement of those environmental parameters which change with time. The physical parameters of the ocean and the atmosphere change and interact in complex ways, contributing to changes in the chemistry and biota of the sea.

The Panel Report, "Environmental Monitoring and Prediction," considers in detail all aspects of the problem. In particular, it points out that significant improvements in our National ability to monitor the marine environment can be achieved by the application of available technology to the acquisition of data that describe the environment. However, even when there is available a complete description of the marine environment, the ability to predict its future state will still be dependent on the degree to which we understand the underlying physical processes.

Three major problem areas requiring immediate expansion of basic research concern the interchange of matter and energy between sea and atmosphere, the dynamics of ocean currents, and the nature of the different scales of motion in the sea.

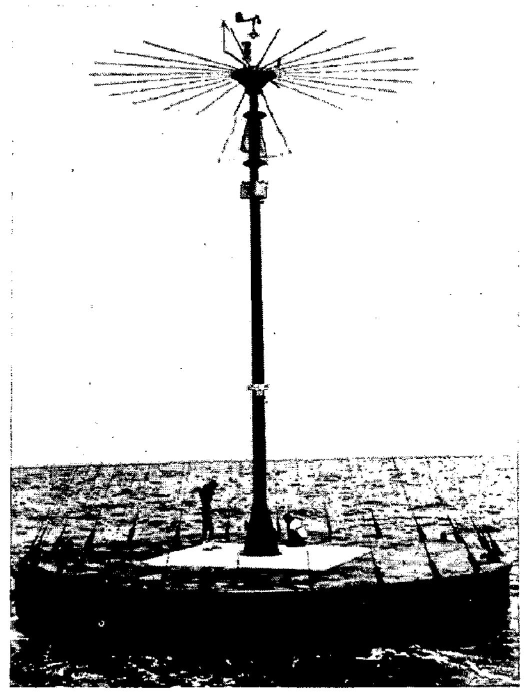

Figure 12. *This surface platform is capable of being moored in deep oceans, collects over 100 oceanographic and meteorological parameters, and can trasmit them to shore stations 2,500 miles away. (Navy photo)*

Recommendation:

Extensive field experiments should be conducted to describe physical processes associated with ocean fluctuations. Parallel efforts in geophysical fluid dynamics should be mounted which can provide the theoretical and practical framework for the establishment of physical techniques for ocean prediction.

The recommendation will be further elaborated in the next three sections.

A. Air-Sea Interaction

Many aspects of research in air-sea interaction are now beginning to receive attention. However, much more remains to be done. The most obvious interchanges between sea and atmosphere are those of water, heat, and momentum. Careful measurements of radiation, temperature gradients in the lower atmosphere and upper layers of the sea, precipitation and humidity in the air, salinity at the sea surface, and the formation and break up of sea ice, can lead to understanding of the mechanisms of these major exchanges.

There are, however, many other types of exchanges between oceans and atmosphere, some exceedingly subtle in their requirements for observations, all of which need to be studied in detail. Energy is transferred from wind to ocean as kinetic energy of waves and currents, and although techniques are available for forecasting the ocean surface waves and currents resulting from interaction with a wind field, they are still semi-empirical. Non-linearity of the interactions, and the stochastic nature of the processes involved, make wholly theoretical solutions extremely difficult to formulate.

Severe storms, particularly tropical hurricanes, may greatly modify the ocean layers over which they pass, mixing the surface layers to produce profound temperature and salinity changes. Conversely, tropical hurricanes are generated solely over the ocean surface and deteriorate rapidly over colder water or land.

Solid particles are likewise exchanged between the sea surface and the atmosphere. Solid nuclei play important roles in cloud physics, and their absence may be a limiting factor controlling precipitation. Some of these nuclei originate from salt spray; other atmospheric particles originating as terrestrial or cosmic dust form a significant fraction of pelagic oceanic sediments.

Gases interchanged between the atmosphere and the sea surface form still another category of material involved in air-sea interaction. A detectable secular increase of atmospheric carbon dioxide has been traced to industrial combustion of coal and petroleum, raising the question of what effect this might have on the dissolved carbon dioxide content of the ocean.

A broad attack on the theoretical and technological problems of providing adequate world wide meteorological information is now being planned and coordinated by the World Meteorological Organization under the designation of the World Weather Program.[20] As part of this activity, undertaken jointly with the International Union of Geodesy and Geophysics and the Intergovernmental Oceanographic Commission, the World Meteorological Organization is planning a Global Atmospheric Research Program. The Intergovernmental Oceanographic Commission is embarked upon an "Integrated Global Ocean Station System" which is the ocean analogue of the World Weather Program. Both of these programs call for a much expanded effort to understand the interaction between the ocean and the atmosphere.

Parallel activity is being initiated by all interested agencies of the United States Government and university groups. The first series of comprehensive sea-air interaction field experiments are scheduled for the summer of 1969 off Barbados.[21]

Critical importance attaches to the understanding of the interaction between ocean and atmosphere, on the one hand for predicting the state of the oceans and on the other for predicting the state of the atmosphere.

Recommendation:

The Nation should continue to place a high priority on comprehensive field experiments to understand air-sea interaction processes.

B. Dynamics of Ocean Currents

Ocean currents may be superficially likened to the winds of the atmosphere, but except for the trade winds they are significantly different in their persistence and behavior. In the temperate and polar regions of the earth, regions of low pressure tend to drift from west to east around the earth, bringing with them weather patterns that commonly persist only for a few days. The wind at any given locality in these regions may blow north for several days, and south for the following days. Ocean current systems, at least on an oceanic scale, persist season after season in the same geographical areas. The meridional advection of heat by these persistent ocean currents has far-reaching effects on climate and fluctuations in the transport of these current systems are very likely one of the main causes of variations in average temperature, rainfall, and other meteorological characteristics of most of the earth's surface.

[20] *World Weather Watch–the Plan and Implementation Programme,* World Meteorological Organization, May 1967.

[21] *Plan For a Major Field Experiment in Support of the Federal Air-Sea Interaction Program,* Report to the Joint ICO/ICAS Panel on Air-Sea Interaction by the Sea-Air Interaction Laboratory, Institute of Oceanography, U.S. Environmental Science Services Administration, March 1967.

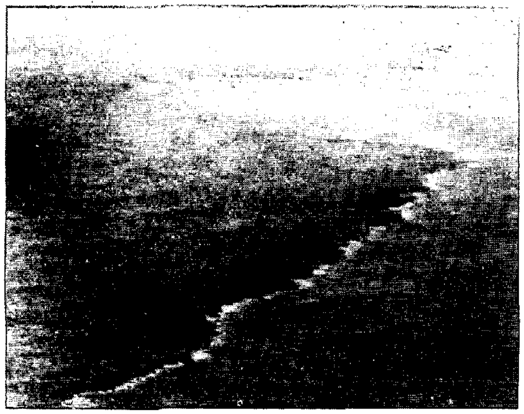

Figure 13. *Florida Gulf Stream. Typical meandering of the Gulf Stream is evident by color contrast and Sargasso weed accumulations at the Stream margins. The darker color represents the warmer Gulf Stream water. The photo represents the usefulness of photography in differentiating some oceanic features. (NASA photo)*

Recent observations have shown that the pattern of permanent ocean currents near the Equator in all the oceans is highly complex. There are broad equatorial currents, flowing westward in a manner that would be expected as a response to the westward component of the trade winds on both sides of the Equator. But, in addition, an intricate system of powerful equatorial countercurrents exists at the surface and at relatively shallow depths below the surface. Although various mathematical models have been proposed to account for these current systems, at best we have only approximate steady state models.

Attack on the problems of predicting fluctuations in major ocean currents will require both an extensive series of field observations to describe their actual behavior in nature and research in geophysical fluid dynamics to account for the observed properties of the currents in terms of the inputs of thermal and wind energy on a rotating earth.

Extensive efforts, both observational and theoretical, have been carried out in recent years by various government agencies and private scientific institutions. The ability to mount meaningful observational programs in the ocean as well as to develop theoretical models has increased markedly in recent years. There have been substantial international collaborative efforts to study ocean current systems such as the International Cooperative Investigation of the Tropical Atlantic and the Cooperative Study of the Kuroshio and Adjacent Regions.[22] These efforts should be intensified; the time has come to marshal the Nation's scientific and technological capabilities to plan comprehensive attacks on outstanding problems of ocean circulation dynamics, both in the field and in the laboratory.

Recommendation:

The Nation should undertake a series of systematic investigations into the oceans' current systems to study their dynamics through cooperative field investigations, marshalling at one time multiple ship, buoy, and aircraft arrays, as well as an expanded effort in the theoretical and mathematical modelling of such systems.

C. Scales of Motion

Superimposed on the great river-like flow patterns of oceanic circulation and tending to obscure their details whenever observations are closely spaced, either in distance or in time, is a complex pattern of smaller scale motions. Some of this motion is associated with internal waves on interfaces between layers of differing density. Some of it takes the form of eddies and gyres with dimensions ranging from meters to hundreds of kilometers. Such motion appears to be responsible for most mixing in the sea.[23]

Studies of the characteristics of these motions have revealed that appreciable energy is involved, whatever the frequency or scale investigated. Further investigation of these motions, by direct observation, by operation of hydraulic models, and by computer simulation, is needed to account in detail for the mechanisms by which they are produced and by which energy is transmitted from one type to another.

This problem is fundamental, not only to the ability to understand oceanic processes in order to begin to simulate these processes mathematically as well as in the laboratory, but to determine the nature of the sampling intervals required for ocean

[22] Established by Intergovernmental Oceanographic Commission Resolutions II-7 and III-5 respectively.

[23] *Organized Convection in the Ocean Surface Layer Resulting from Slides and Wave Radiation Stress,* Kraus, Physics of Fluids, Vol. 10, No. 9, pt. 2, 1967.

observation networks whose data will be the basic input for ocean and weather prediction techniques. Recommendations to the Federal Government have been made consistently by the National Academy of Sciences Committee on Oceanography[24] and the President's Science Advisory Committee,[25] with little response. The time has come to take action. With the decision of the Government to move forward with a major ocean buoy development program under the aegis of U.S. Coast Guard, the time is at hand when technology will permit a major assault on the problem.

Recommendation:

There should be initiated as soon as possible a well-defined program to study oceanic scales of motion and such a study should be one of the early foci for the test of the elements of the National buoy program.

[24] *Oceanography 1966*, National Academy of Sciences, National Research Council, Pub. No. 1492, 1967.

[25] *Effective Use of the Sea*, Report of the President's Science Advisory Committee, 1966.

Historically, the security of the Nation has been fundamentally tied to the ability of its Navy to operate effectively in and under the sea, over all of the oceans of the world. The basic marine science effort of the Nation has been crucial in maintaining naval capabilities abreast and ahead of any potential enemy. The Navy's operations are so far flung, so complex, that there is hardly an area of marine science which does not bear directly on the effectiveness of its operation. It has been the agency which, out of self interest, has fostered and supported by far the largest fraction of basic marine science research in this Nation. It has conducted its stewardship well. It is largely through the support of the Office of Naval Research that the Nation's eminence in basic marine science was developed.

The Office of Naval Research, which directs the Navy's basic science research effort, has, since its creation in 1946, played a historic and unique role in the Nation's science growth. It has been notable for sponsorship of long-term studies. It has also provided ships for the use of its contract institutions, and has, in general, supported a broad spectrum of basic research in all sciences. Its programs have done much to bring the Navy to its present state of scientific excellence.

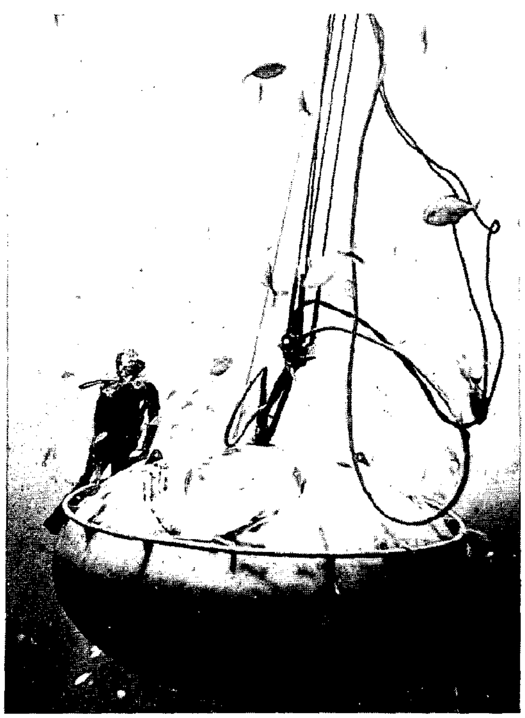

Figure 14. *Many modern arrays utilize subsurface floats such as this one for the Seaspider Buoy System to support the instrumentation. Scuba is often used in maintenance of oceanographic research equipment. (Navy photo)*

The Navy of tomorrow may well operate in a context which a generation ago would have appeared implausible. It may include operational underwater habitats, deep submersibles and complex structures on the ocean bottom.

The Navy today is engaged in an imaginative man-in-the-sea program, designed to demonstrate that its forces can not only survive but work effectively in an underwater habitat and overcome progressively the depth and other environmental limitations on such operations. It is concurrently engaged in developing a capability not only to operate deep submerged vehicles but to conduct rescue operations on a world-wide basis. It is also engaged in the development of buoys and buoy systems as means for sensing and recording oceanographic data of significance to basic research as well as to naval operations.

These programs are typical of areas in which the Navy will continue to develop, in addition to more traditional roles.

Aspects of National security are involved in many of the areas considered in the panel's report, particularly in environmental monitoring and prediction. In addition to the matters discussed, many other aspects of basic research are important to the Navy.

In its 1967 report, "The Navy's Ocean Science Program,"[1] the Navy named eight areas considered worthy of research in the interest of National defense: ocean dynamics, air-sea interaction, oceanic chemistry; benthic boundary studies, sea floor topography and sediment, crustal and subcrustal composition, oceanic biology, and underwater sound. It added that the emphasis will change from year to year, "as our realization of potential application grows."

[1] *The Ocean Science Program of the U.S. Navy*, Office of the Oceanographer of the Navy, 1967.

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Still other areas will shortly be ripe for further research effort, if in fact they are not already. Among them are hyperbaric physiology of mammals, soil science and technology, and further understanding of turbidity currents. Numerous others might be mentioned.

It is certain, in our view, that the effectiveness of the Navy of tomorrow will be determined in considerable part by our level of scientific understanding of the marine environment, and that all aspects of basic science in this area are of concern to it.

In the light of this assessment, the panel urges strongly that the Navy maintain the broadest possible view of its obligations to support basic marine science.

Recommendation:

The Department of Defense should continue to recognize, as it has in the past, the vital nature of all aspects of basic marine science research to its naval missions, and adopt the broadest possible view of its obligations to insure that the National basic marine science effort meet not only its short-term needs but future requirements for marine information. It also should continue to function as one of the cornerstones for the support of the Nation's basic marine science effort.

The ability to see, detect, or destroy the underwater enemy depends fundamentally upon an understanding of energy propagation through water and the effect upon such energy propagation by the ocean bottoms, the air-sea interface, etc. Electromagnetic energy such as light, radar, and radio waves is quickly attenuated in the ocean. Acoustical energy is known to propagate over long distances in water. The capability to develop techniques and equipment which will enable use of acoustical energy as a basis for detection depends on knowledge of how the ocean structure affects such energy propagation.

This has been an area of basic science to which the Navy has given prime attention and its detection capabilities are formidable. The importance of the problem cannot be overstated. The panel, recognizing the extensive effort maintained by the Navy in the field of underwater acoustics, nevertheless feels that understanding of the effect of the boundary between air and water, in terms of acoustic reflections and refractions as well as the effects of the bottom topography and the inhomogeneities of water masses, can be significantly improved through additional research.

Recommendation:

The Navy should maintain and, as required, expand its underwater acoustic research program.

Science and technology are reciprocal spurs. Joined in proper measure, they can bring mutual advances of enormous import. In marine science, because of the difficulty of operating in the oceans, the relationship must be closer than in many other fields of science. Technology makes it possible to sample the deep ocean bottom, live and work in the oceans, and acquire the data that science needs for its marine effort. Yet, in general, basic science and marine technology have failed to achieve the level of partnership necessary to the advancement of many fields of marine science.

It is true that outstanding examples can be cited, such as the use of deep drilling techniques for exploring the geophysical structure of the ocean bed. Yet examination of the activities at major ocean science laboratories in the academic community and in some Federal laboratories shows only marginal attention being paid to provision of the kind of modern engineering support which the growing problems in ocean science require. On the other hand, there is a vigorous marine and general engineering competence in industry but, for reasons not always easy to understand, that competence has not generally been directed toward the solution of basic science problems.

In their prepared statement at the panel's hearings, Dr. R. A. Ragotzkie and C. H. Mortimer, University of Wisconsin, said:

The schism between natural scientists and engineers must be bridged by processes of education of both groups and by a recognition by fund granting organizations that engineering talents are needed in many environmental research activities.

The report of the Panel on Marine Engineering and Technology has addressed the problems of the need for technology in the National marine science program, giving extensive descriptions of the advances to be expected in the next decade. This report focuses upon the needs of the scientist for technology.

The total development of marine science has suffered from a failure to provide the proper kinds of engineering support. Too few engineers have been brought into the field to work on basic marine science problems, although much of the engineering and technology being developed for other reasons is susceptible to marine science use today.

The lack of adequate engineering development skills specifically associated with basic research is limiting development in some areas. In physical oceanography, for instance, Professor Henry Stommel of the Massachusetts Institute of Technology, said in a statement at the panel's hearings: "I don't think that either scientists or engineers realize the time and funds needed for good engineering in ocean instruments."

Besides retarding the rate of progress in field experimentation, this deficiency is costly. In the fields of space or communications, it would be considered unthinkable to deploy expensive operations without properly engineered equipment of at least reasonably assured dependability. In marine science, however, it is not unusual to expect a high failure rate for equipment.

The panel is struck by the number of key technological developments now under way which will have a radical impact on the kinds of specific problems it will be possible to attack, as well as on the manner in which basic science itself will be conducted. Several of these developments will bring within reach an approach to problems which previously could only have been attacked at forbidding cost, or not at all. For example, the sophisticated modern sonar ought to be used more for biological research. The background noise so troublesome to the Navy is often primary data to the biological oceanographer.

Data-sensing unattended buoys, in the next decade, will finally put oceanography in a position to describe the physical state of the seas and enable scientists to understand their fluctuations and to test theories for their prediction. The buoys also hold potential for the measurement of biological and chemical constituents of the oceans. While today the sensor systems for the automatic measurement of biological and chemical variables are limited, their development is clearly going to occur. Once operational, the data they produce may revolutionize understanding of biological processes in the ocean and the relation of those processes to the changes of the physical environment.

The development of oceanographic-sensing earth-orbiting satellites is now under way. They will, over the next decade, have the capability of measuring such surface conditions as temperature and sea state, providing an entirely new method of global assessment of these conditions.

Technological developments in deep ocean drilling pioneered by the oil industry are being used in the Ocean Sediment Coring Program, funded by the National Science Foundation, to provide deep cores of the crust, with attendant studies of the oceans' geophysics and geology.

The use of deep submersibles can lead to important scientific results now obtainable, if at all, only with great difficulty from surface vessels. A submersible equipped to make temperature-gradient measurements in marine sediments could obtain better data faster than a fleet of surface craft lowering probes on long wires on the present hit-or-miss basis. A submersible capable of making a systematic traverse of the Mid-Atlantic Ridge, say just south of Iceland, taking magnetic and gravity readings and drilling short cores to sample the rocks could convert sea floor spreading from a theory to an accepted scientific principle (or to an outmoded hypothesis). An under-ice penetration by submersible below the Antarctic ice sheet could bring back in a few weeks more data on the biological conditions in this unique habitat than could be obtained by months of sampling through holes drilled through the ice.

There is no question that technology will give us a capability for the operation of manned underwater habitats, which can be used for the study of ecology and animal behavior in the marine environment.

The way in which we operate our oceanographic research vessels is undergoing rapid and continuing change. On-board automatic data processing is becoming feasible and total systems for automated data acquisition through on-board analysis of results will speed tremendously the efforts of scientists at sea by the elimination of long waits for feedback.

Technological developments clearly will have a pervasive impact upon basic marine science—yet the basic science community is failing to have a similar impact upon the field of marine technology. Except in isolated cases, the marine

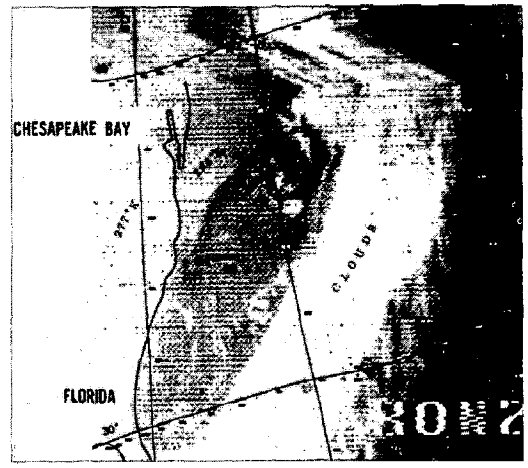

Figure 15. *IR imagery of Gulf Stream. Nimbus II high resolution infrared imagery clearly depicts the Gulf Stream. Temperature values were determined by microdensitometer. Nimbus IR imagery can be very useful in determining the location, distribution, and movement of major ocean water masses. Studies of this nature will be of great value to oceanographers, meteorologists, and the world's fishing and shipping industries. (NASA photo)*

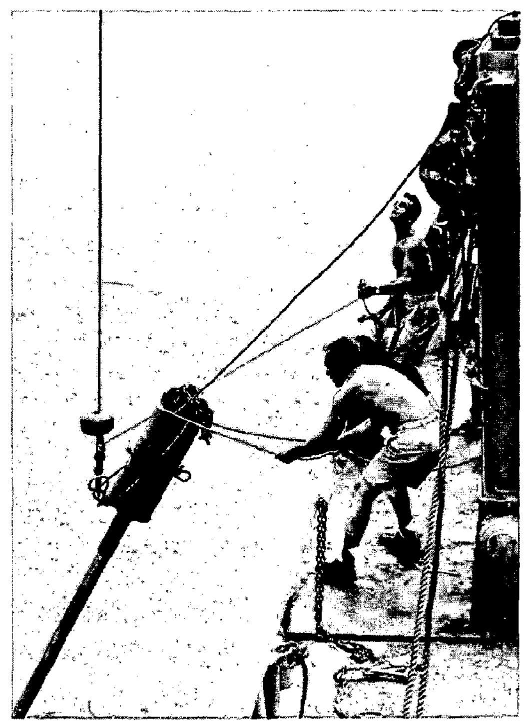

Figure 16. *Retrieving a corer from the sea bottom. Cores showing the vertical structure of bottom sediments up to 50 feet below the ocean floor have been obtained. These cores are used to determine the history of geologic processes. (National Science Foundation photo)*

science community seems to be willing simply to use whatever technology is available. Basic marine science has important needs for special technology and should recognize the fact and make those needs known. It should further foster, within its own laboratories or through close working arrangements with industry, the development of technology needed for undertaking basic research. For example, technological development should be fostered in the handling of biological and geological samples, data processing, remote sensing instruments, and specialized sampling devices.

Basic scientific inquiry into the nature of the oceans is important enough to warrant the encouragement of technological development in key areas purely for the achievement of basic understanding. On the basis of this conviction, and in the light of the present degree of separation between technology and basic marine science, the panel strongly urges the following:

Recommendation:

Efforts should be initiated to increase participation of the private sector in instrument development and other marine engineering work. The major academic institutions should establish, or insure access to, groups with advanced engineering competence to work closely with marine science groups. Some technology development should be encouraged purely for the achievement of a better understanding of the oceans.

The Nation now possesses a healthy program of graduate training in marine science and as a consequence has available a supply of young research-trained scientists sufficient to support an immediate expansion in the effort in this field. Nevertheless, over the longer term, a fully developed national program of basic research must be accompanied by an expanded level of trained manpower entering the field.

Inasmuch as a full discussion of the problems that will be involved in maintaining an adequate supply of trained manpower to meet all the requirements of ocean resource utilization is contained in the Commission's Staff Study on Education and Manpower, this report will consider solely the needs for manpower concerned with basic research. These needs can be identified in terms of four main levels of training: the postdoctoral level, the doctoral candidate, the bachelor/master's degree student, and the technician.

Doctoral candidates in oceanography are now drawn from the top ranks of holders of bachelor's degrees in one of the appropriate basic fields of study: mathematics, physics, chemistry, geology, or biology. The Council of Laboratory Directors, made up of the 10 largest oceanographic institutions,[1] has reported that in 1967 only 286 out of 1,884 student applicants were accepted.[2] Even allowing for a considerable margin of duplication among the student applicants to the various schools, these figures make it clear that the choice of individuals as entrants into present doctoral programs has become a highly selective process.

Under an expanded program of ocean exploration and exploitation, the increased public attention that will be given to ocean science as a profession can be counted on to maintain the present desirable trend and to guarantee continued crops of highly qualified applicants to the graduate schools. Gradual expansion of the present capacity of the graduate schools will result in an increasing supply of trained researchers in ocean science with no danger of diminishing the present high quality.

The 1967 manpower study of the International Oceanographic Foundation identified 610 Ph.D. holders active in the profession; 325 of these reported basic research as their primary occupation and 175 (including 136 university people heavily engaged in teaching) reported basic research as their secondary occupation.[3] Thus 500 of the 610 Ph.D. degree-holders in the comprehensive sample collected by the International Oceanographic Foundation, or over 80 per cent, are engaged in basic research.

Of these 610, less than a third (169) had received doctorates in oceanography, marine science, or fisheries, whereas nearly 70 per cent (420) had received it in other disciplines. Biological sciences had supplied 215, geology 98, chemistry 28, physics 23, and other physical sciences 56. The field was not identified for 21.

Corresponding figures for 1964 were 353 Ph.D.'s, of whom 103 earned their degrees in oceanography, marine science, and fisheries, 123 in biological sciences, 49 in geology, 12 in physics, 11 in chemistry, 17 in other physical sciences, and 38 in unidentified specialties. In this group, 211 were engaged primarily and 84 secondarily in basic research; the total of 295 is likewise over 80 per cent of the total sample of 353.

The proportion of doctorates in oceanography, marine science, and fisheries was virtually the same in both surveys, 29 per cent in 1964, and 28 per cent in 1967.

These figures show that manpower for conducting basic oceanographic research is not primarily limited to the output of trained doctorate degree holders from university departments of oceanography and marine science. The situation in the oceanographic profession is unlike that in the

[1] Woods Hole Oceanographic Institution, University of Rhode Island, Lamont Geological Observatory, Johns Hopkins University, University of Miami, Texas A&M University, Scripps Institution of Oceanography, Oregon State University, University of Washington, University of Hawaii.

[2] *The Role of Academic Institutions in the Development of Marine Resources and Technology*, Report of the Council of Oceanographic Laboratory Directors, 1967.

[3] *A Study of the Numbers and Characteristics of Oceanographic Personnel in the United States, 1967*, prepared by the International Oceanographic Foundation under National Science Foundation Contract C-469, 1967.

medical profession, for example, where any expansion in the total numbers engaged must involve first an increase in the capacity of the medical schools. The conclusion to be drawn from such statistics is that National oceanographic basic science effort cannot be considered limited by the availability of potential students and trained manpower at oceanographic institutions.

The supply of oceanographic technicians, on the other hand, particularly of seagoing technicians and technicians competent to operate and maintain the growing arrays of complicated sensing, recording, and analytical devices used on research ships and at research institutions, is likely over the short term to prove the most critical manpower area in basic marine research. Personnel in these, categories are highly mobile, both within the ocean science and technology field and outside it to such areas as commercial fishing, space science, chemical industry, and exploration geophysics. Therefore, it is urgent to foster the establishment of additional training programs for marine technicians. These programs should involve junior colleges and technical institutes, which should be provided with suitable training vessels and prototype examples of equipment.

Requirements for baccalaureates in oceanography and for baccalaureates in basic science with master's degree in oceanography are considerably less in the area of basic academic research than they are in the technological and administrative fields related to ocean exploration and utilization. Such individuals are employed in research organizations chiefly as scientific aides and they have a higher degree of mobility than the doctoral degree holders. It appears, therefore, that whatever expansion in training is necessary to produce the numbers required for increased industrial and governmental involvement in ocean surveys and ocean resource exploitation can be counted on to produce numbers in this category that will be adequate to meet basic research needs even for an expanded program.

The Nation is better equipped than ever before in resources both of trained manpower and of supporting facilities to mount an expanded program of basic research on the ocean. This trend is a desirable one and its continuation should be encouraged. However, before such scientists can become effective contributors to the expanding

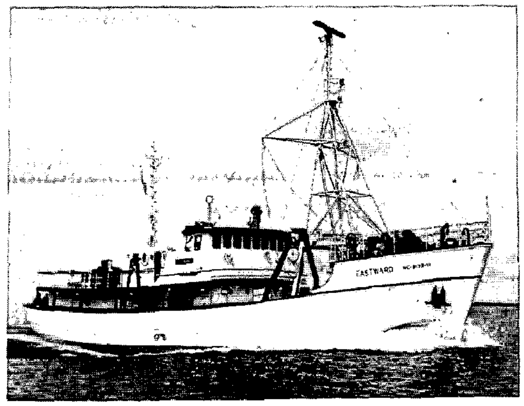

Figure 17. *Research training ship* Eastward, *is a successful experiment in training oceanographers at sea. Heretofore, difficulty in manpower utilization was in obtaining shipboard time for training.* Eastward, *funded by the National Science Foundation and operated by Duke University, has shown that training and research can be accomplished simultaneously. (National Science Foundation photo)*

body of scientific knowledge about the oceans, it is necessary for them to acquire some firsthand familiarity with the properties and characteristics of the ocean environment. Such indoctrination can be experienced in many ways, but it is best undergone at a large university department of marine science or at an oceanographic laboratory or institution. Here, as a member of an interdisciplinary team, the young scientist can apply his newly learned specialty to assist in the solution of some problem concerning the ocean; at the same time he can acquire by direct observation the knowledge of the behavior of the ocean as a system relating to his specialty, enabling him in time to lead his own research team. Therefore, an important part of the arrangements for an expanded program of professional training must be provision for support of postdoctoral programs at marine science research centers.

Although the methodology of estuarine studies and coastal oceanography involves most of the same basic principles and operations as the conduct of research on the high seas, it nevertheless contains much that is unique to its particular requirements. For this reason, a body of regional specialized knowledge must be assembled and drawn upon to meet the unique requirements of each locality. Estuarine and coastal research centers should develop appropriate training programs in their specialities, having due regard to their specific geographical situations.

Recommendation:

The major educational institutions should be encouraged to maintain the vigor of their graduate and postdoctoral programs; estuarine and coastal research centers should develop appropriate training programs in their specialties; additional training programs for marine technicians should be created.

Implementing a materially expanded program of basic research in marine science will require the proper mix of manpower, money, and institutional arrangements. If the funding is forthcoming, the manpower outlook is favorable. In this section, the panel addresses the institutional and facility needs of such a program.

The institutional arrangements available to the Nation today for the conduct of the programs outlined are extremely diverse. They represent a sound base on which arrangements adequate to growing needs can be built. But they are not now adequate to a task of the magnitude envisioned. Basically, there is an emerging need for institutional arrangements designed to cope with the problems of "big science" on the one hand and highly specialized local problems on the other.

Basic ocean science requires large and complex facilities. While they are relatively modest compared to those the Nation maintains for space, nuclear, and health science programs, they are large compared with ocean facilities presently available. It is important for the continued health of basic marine science that university laboratories be able to operate major facilities comparable to those operated in the Federal establishment.

The problem of assuring adequate and stable support for institutional facilities was the one most often emphasized in the panel's hearings, in interviews, in letters received, and in a formal response from the National Academy of Sciences Committee on Oceanography to a panel query. In this general area of facility support lies one of the most troublesome obstacles facing the research community today.

The problem of facility support is a difficult one. Twenty years ago the requirements were for a few small general purpose research vessels. Today the needs range from conventional research ships to platforms such as FLIP, deep-drilling vessels, deep submersibles, underwater laboratories, large buoy arrays, experimental coastal engineering structures, and large open areas where it is possible to practice limited environmental control.

As the need for specialized facilities has grown, so has the size and complexity of the institutions. The three largest oceanographic research institutions over the past 15 years have been the Scripps Institution of Oceanography of the University of California, the Woods Hole Oceanographic Institution, and the Lamont Geological Observatory of Columbia University. Some measure of their growth can be seen in Table 13. Today there are at least five additional academic institutions which are comparable in size to Scripps and Woods Hole in 1950. But it is obvious that the Nation cannot provide a full complex of facilities to all laboratories or groups which would want them. Moreover, the program envisioned would not require them.

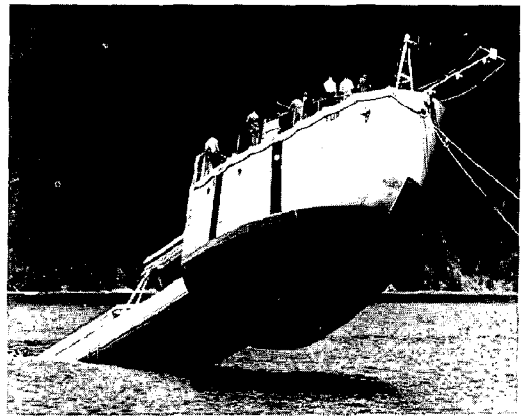

Figure 18. *Floating Laboratory Instrument Platform (FLIP) at Dabob Bay. This platform, requiring no surface support ship once it is on location, may be towed as a ship and then ballasted to a vertical position. Able to support scientists at sea for long periods, its unique depth allows precise scientific measurement to be obtained. (Navy photo)*

Institutional arrangements must be established to provide for the necessary concentration of expensive facilities and still make sure they are available to all who need them. The Nation has confronted this problem before, in atomic energy, space, astronomy, and atmospheric science programs, through the establishment of certain nationally designated facilities.

At the other end of the scale, some of the most urgent marine science problems are those of the coastal zone, which are highly localized and highly specialized. Present institutional arrangements do not provide for the necessary facilities and institutions to attack these problems.

Table 13. COMPARISON OF THREE OCEANOGRAPHIC RESEARCH INSTITUTIONS

SCRIPPS INSTITUTION OF OCEANOGRAPHY

	1950	1955	1960	1965	1968
Professional Staff	42	105	105	142	187
Annual Budget (in millions of dollars)	1.1	2.9	6.6	10.2	13.8
Space (in thousands of square feet)	72	98	169	267	307

WOODS HOLE OCEANOGRAPHIC INSTITUTION

	1950	1955	1960	1965	1967
Professional Staff	40	65	105	112	143
Annual Budget (in millions of dollars)	1.1	1.8	4.9	8.7	10.2
Space (in thousands of square feet)	41	69	74	128	148

LAMONT GEOLOGICAL OBSERVATORY

	1950	1955	1960	1965	1967
Professional Staff	10	20	40	60	66
Annual Budget (in millions of dollars)	0.2	0.9	1.9	6.0	6.1
Space (in thousands of square feet)	11	15	19	79	122

The panel also has identified a number of institutional funding problems. They will be discussed in the section on Federal organization.

In the sections that follow, the panel discusses a variety of necessary institutional arrangements which it believes essential.

I. THE NEED FOR DIVERSITY

Important discoveries in oceanography have been made in the major university institutions, in government laboratories, in small institutions, and by scientists with no formal connection to any oceanographic department or laboratory. Furthermore, the scientists who are now most active in oceanography received their training in a variety of ways, some in large institutions, some in small, many entering the field from other disciplines.

There is no single best way to produce either oceanographic science or oceanographers and it would be a mistake to support one institutional arrangement to the exclusion of others. Although a similar statement can be made about nearly every field of science, it is particularly pertinent in oceanography. More than most sciences, it is interdisciplinary. Discoveries and techniques from other fields are being continually applied to problems in oceanography. Oceanographic horizons are expanding so rapidly it would be incorrect to suggest that all or even most progress will be made in a single class of laboratories or by persons with a particular type of training; there is a need for various kinds and sizes of marine laboratories in the Nation.

Because of the diverse and expanding nature of the field, it is almost impossible to find agreement on a simple definition of oceanographic institutions or oceanographers. If one accepts a simple operational definition such as "oceanography is done by those working at oceanographic institutions and oceanographic institutions are those laboratories with sea-going facilities," one is left with the following kinds of problems: important work on oceanic circulation theory has been done at Harvard University,[1] geotectonics of the sea floor at Princeton University,[2] tsunamis and wave run up at the University of Wisconsin,[3] and the geo-chemical balance of the ocean at Northwestern University,[4] all by men with few, if any, formal ties with oceanographic institutions.

If one assumes that oceanography is that which is published in oceanographic journals, he can by a perusal of the collected reprints for 1966 of the Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution (two oceanographic institutions by everyone's definition) find that some 287 articles were published in more than 60 different journals, most of which are not generally considered oceanographic journals.

Although the fact that there is no simple definition of oceanography is distressing to the auditors and census takers of science, it represents one of the Nation's greatest strengths in marine science.

Recommendation:

The present variety of institutional arrangements for the development and support of oceanography is good and should be nurtured. Furthermore, as the horizons of oceanography continue to expand, new institutional arrangements can be encouraged.

II. UNIVERSITY-NATIONAL LABORATORIES

In reviewing U.S. progress in marine science since World War II, the panel is struck by the degree to which the health and vigor of this program and U.S. leadership have depended fundamentally on a small number of oceanographic institutions. These institutions–large, well staffed and relatively well financed–have been largely responsible for the fact that the Nation is in a foremost position in the field.

The major centers of oceanographic research in this country are those that automatically come to mind when the National oceanographic program is discussed. Such institutions as the Scripps Institution for Oceanography, Woods Hole Oceanographic Institution, Lamont Geological Observatory, and others epitomize the eminence of the National effort. They represent a major National investment. In formulating plans for suitable institutional arrangements for the National marine science effort, it is the strong view of the panel that we must build on our present sources of strength and experience. The panel is convinced that it is in the best National interest to do so.

While future U.S. leadership in this field will require additional kinds of institutions, these outstanding institutions will remain a vital part of the base of the American effort and could be centers around which rapid and energetic growth can take place.

There is a need for large laboratories equipped with the complex and costly facilities that can undertake any task of a global, regional, or local nature and have the capability to initiate new and imaginative programs. It is important that they have sufficient "institutional support" from the Federal Government to maintain their stability, thus permitting their scientific staffs to have extensive latitude in determining the programs to be pursued.

One of the problems encountered consistently in examining the activities of large and presumably well funded laboratories outside the Federal Government has been the lack of provision of institutional support. Most Federal funding of oceanographic institutions take the form of "project" support. Project support enables the Federal Government to buy specific services or research from oceanographic institutions. From the laboratory point of view, project support creates few problems as long as it is stable and long term. However, project support has not provided adequate long-term stability for oceanographic laboratories to maintain staff or adequate flexibility to enable staff scientists to pursue problems of opportunity as they arise.[5] Institutional sup-

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[1] "An Investigation into the Wind as the Cause of Equatorial Undercurrent," Robinson, Journal of Marine Research, Vol. 24, No. 2, 1966.

[2] *Midoceanic Ridges and Tectonics of the Seafloor,* Hess, Submarine Geology and Geophysics, Proceedings of Seventeenth Symposium of the Colston Research Society, 1965.

[3] *Some Three-dimensional Effects in Surf,* Meyer and Turner, Journal of Geophysical Research, Vol. 72, No. 10, 1967.

[4] *Silica: Role in the Buffering of Natural Waters,* Garrels, Science, Vol. 148, No. 3666, 1965.

[5] *The Role of Academic Institutions in the Development of Marine Resources and Technology,* Report of the Council of Oceanographic Laboratory Directors, Sept. 12, 1967.

port implies the provision of funds on a long-term basis only generally constrained for broad program purposes. Institutional support should also enable research laboratories to provide their scientists operating facilities such as ships or shore-based laboratories on a consistent basis.

To meet the emerging National needs for adequate facilities by all scientists engaged in basic marine research, the Nation should designate a small group of laboratories—which should include but not be restricted to those which today provide the national leadership—as "university-National laboratories." They should be distributed geographically to cover different parts of the ocean efficiently. They should be provided with adequate facilities for undertaking worldwide deep ocean programs in basic science. These laboratories should be accorded adequate institutional support in return for which they would commit themselves and their facilities to serve the needs of scientists and scientific groups affiliated with other organizations.

There is apparently nothing exactly analogous to what we are suggesting in the array of Federal-academic partnerships, although one can find parts of this concept in the arrangements of such institutions as Brookhaven National Laboratory of the Atomic Energy Commission and the National Center for Atmospheric Research of the National Science Foundation.

The direct management of these laboratories should be assigned to universities, which would make formal provision for the advice and assistance of other academic institutions not designated as university national laboratories in accordance with guidelines set forth by the Federal Government.

Without prejudging the exact nature of these arrangements, it is suggested that insofar as possible these National laboratories should not be started afresh, but should build upon existing facilities in the academic community. The facilities and programs of these university-National laboratories need not be identical. Although the exact nature of the Federal-university partnership may vary from institution to institution, it is necessary that the university be an active partner. There should be some university commitment for continuing support and activity in the marine sciences. The university must be more than a manager; it must have some stake in the program. University-National laboratories must make some formal provision for providing for outside investigators. In return for being furnished the facilities which will

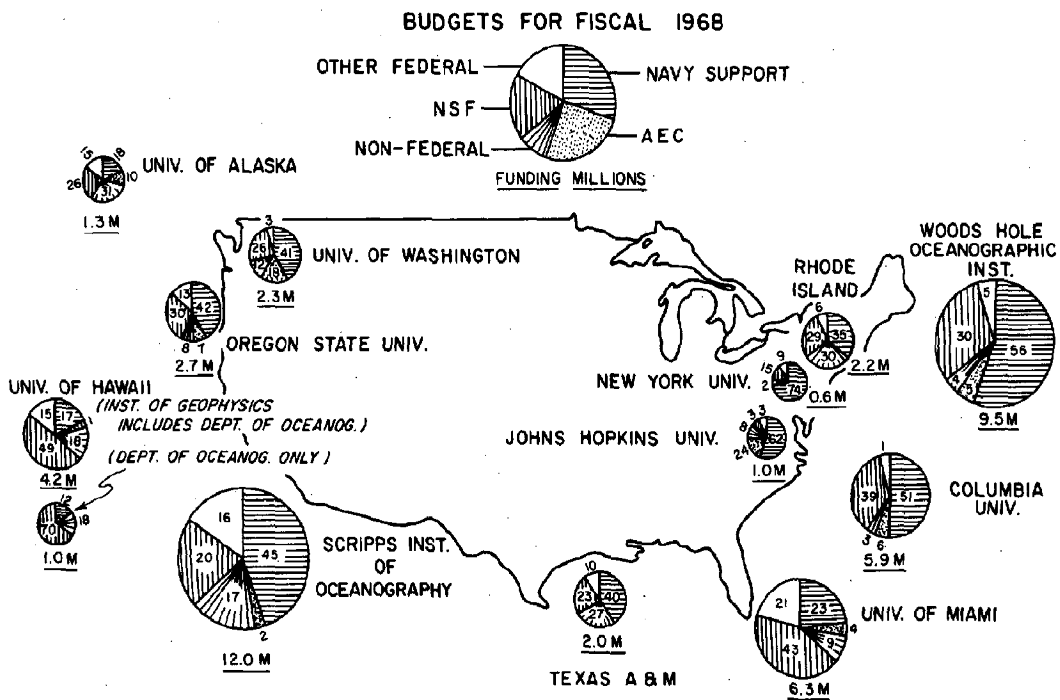

Figure 19. *Major oceanography laboratories. (Photo by W. Burt)*

enable the institution to play a leadership role, it must provide some formal mechanism for allowing visiting scientists to share these facilities.

How large these university-National laboratories might become and how many might be established is dependent upon many factors. Considering the present and projected growth of the national oceanographic program, we are inclined to think that no more than a dozen such institutions should be designated. Whatever the number, some effort should be made to provide geographic distribution. For example, there should be university-National laboratories on the Atlantic and Pacific Coasts as well as one each on the Great Lakes and in the Arctic, and one in Hawaii.

One of the key desiderata of the university-National laboratory will be to foster the partnership between marine science and technology. There should be established within such laboratories the necessary engineering staffs and engineering support facilities, or arrangements should be made for close affiliation with engineering groups in industry or engineering departments of universities.

Recommendation:

A small group of institutions, which should include but not be restricted to the acknowledged leaders, should be designated "university-National laboratories." They should be distributed geographically to cover different parts of the ocean and should be provided with adequate facilities for undertaking global deep ocean programs in basic science. Their facilities should be available to scientists at other universities and Federal laboratories for related basic science activities. They should be accorded adequate institutional support for maintenance and operation, and in turn should commit themselves and their facilities to serve needs of scientific groups affiliated with other institutions. Such an institutional arrangement will insure that the Nation's leading oceanographic institutions will be provided adequate resources and support to insure their continued health and vigor.

III. COASTAL AND ESTUARINE LABORATORIES

The need for better understanding and management of our coastal-estuarine zones and the Great Lakes is evident.[6] The problems have been enumerated in several reports of the Commission panels, including this one. The problems are many and require the skills of social scientists as well as natural scientists. While the overriding need is for the development of a rational management scheme for these important waters, scientific understanding is critical if information on the complex dynamics, ecology, and chemistry of the area is to provide the basis for rational decision-making.

It is in this general area that the greatest urgency exists. Coastal lands are some of the most desirable in the United States and many actions are irreversible.

The present institutional arrangements for providing the necessary scientific support are deficient in number, size, and quality. The problems of estuaries and near-coastal areas are principally, but not exclusively, of a local or regional nature and vary greatly from estuary to estuary, from coastal zone to coastal zone.

There is a need for the establishment of coastal zone research institutions in association with appropriate academic institutions to provide the basic understanding of coastal and estuarine processes so that Federal, State, and local governments can have available information on which to base rationally their management procedures. These research facilities need not be large in size but should have adequate facilities and staff sizes that exceed the critical limit to maintain a stable program.

There is sufficient difference between estuarine and coastal problems from area to area, and these problems are of such fundamental importance to the welfare of this country, that there should be a university laboratory devoted to basic and applied marine science located on every major estuarine system. The relationships of oil wells to shrimp and oyster fisheries in Louisiana are different from those between pulp mills and salmon fisheries in Washington and the cold water organisms of the coast of Maine have ecological tolerances that differ from those of the warm waters south of Cape Hatteras. Such problems are probably better attacked in university centers in their respective states than through some central Federal or university-National laboratory.

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[6] *Estuaries*, Pub. No. 83, American Association for the Advancement of Science, 1967.

The National Sea-Grant College and Program Act of 1966[7] provides a mechanism for supporting the complex of coastal zone laboratories envisioned. First, the problems are not in the natural sciences alone but in the social sciences as well. Second, many of the problems are "applied" and are in urgent need of a solution. Third, the state has an important interest in the solution of these problems and should be expected to share in the research program.

In the report of the Commission it is recommended that the states take a more active role in the planning and management of the coastal zone. The states will need a cadre of well-trained personnel, which the universities can provide, to help manage these areas.

A difficulty in many states today is lack of the research resources necessary to assist effective planning and managing. Such resources are usually available to the Federal Government through Federal research laboratories and contracts and grants to industry and universities. These coastal zone laboratories should provide the studies and research on which the state may base its management decisions.

Although the relationship of State government to local universities differs from State to State, it is usually closer than that between the State government and Federal laboratories. The coastal zone laboratories should be operated under the Sea-Grant College program, which would provide the necessary resources and expertise to the States that they do not now have. The relationship between a university laboratory and State government will not and should not be identical with that between a Federal agency and its research laboratories. The States will have to maintain their own management and enforcement system and in some cases their own estuarine environmental monitoring system. However, the resources of the university coastal zone laboratories will be available for research, special studies, and assistance just as are those of the agricultural experiment stations and the extension services operated by land-grant colleges.

As in the case of the university-National laboratories, the coastal zone laboratories would not be identical in size or scope. The complexity of the problem in the different states is in part at least a function of geography and economics. It would appear that Florida with a growing population and with 1,350 miles of general coastline bordering both the Atlantic Ocean and the Gulf of Mexico faces a greater range of problems than does New Hampshire with a more stable population and 13 miles of general coastline.[8] States with the geographic coverage of California and Alaska will probably need more than one such laboratory.

The problems are sufficiently different from State to State to require different groups studying their local area, but there are many classes of problems common to all and a degree of specialization within laboratories is not only inevitable but desirable. A complex computer simulation model may be developed for one estuary, but once developed may have more general applicability. The laws governing turbulent diffusion processes are similar, even though their application may vary considerably from case to case.

Recommendation:

A network of estuarine and coastal zone research institutions should be established in association with appropriate academic institutions to undertake the basic and applied research on estuarine processes so that State and local governments can have information on which to base management procedures rationally. These facilities need not be large in size but should have adequate facilities and staff sizes exceeding the critical limit to maintain stable programs. Their activities should be supported under the Sea Grant College Program.

IV. FEDERAL LABORATORIES

Federal laboratories are maintained by the Department of the Interior (Bureau of Commercial Fisheries, Federal Water Pollution Control Administration), Department of Commerce (Environmental Science Services Adminsitration) and others to work on problems of importance to the mission of the agency. Not all of the research needs of the Federal Government can be satisfied by industry and the universities. Traditionally, basic science has been done mostly in university

[7] Public Law 89-688, Oct. 15, 1966, 80 Stat. 998, 33 U.S.C. 1121-1124.

[8] *The Coastline of the United States*, Department of Commerce, Government Printing Office, 1968.

laboratories. However, a certain percentage of every mission-oriented laboratory program has also been devoted to basic research related to its mission. The 1966 National Academy of Sciences Report addressed itself to this problem in some detail.[9] We concur that these Federal laboratories are necessary and that they should continue to devote some of their effort to basic research problems. Such a practice is necessary if these laboratories are going to be responsive to the opportunities as well as the needs of basic science. Such practices are also necessary if the laboratories are to attract and maintain a high level of scientific competence within their organizations.

In recent years, most Federal laboratories devoted to marine problems have been built adjacent to academic centers with strong marine programs. In fact, the Federal Water Pollution Control Act, which established the Federal Water Pollution Control Administration states:

"Insofar as practicable, each facility shall be located near institutions of higher learning in which graduate training in research might be carried out."

In most cases, there is active cooperation between adjacent laboratories from which both profit. Senior staff often serve as lecturers or adjunct professors in the university. Graduate research is supported through the Federal laboratories. Facilities are frequently shared. The practice of siting new Federal laboratories close to university centers should be encouraged.

The panel is interested in the size, distribution, and management of Federal laboratories, and it sees the need for Federal laboratories large enough to meet the Government's needs. A number of new Federal laboratories have been authorized and some have new buildings, but almost without exception they are understaffed and underfinanced. We favor fewer, stronger, adequately equipped and staffed Federal laboratories.

[9] *Oceanography 1966*, National Academy of Sciences-National Research Council, Pub. No. 1492, 1967.

Testimony in panel hearings indicates the need for better management systems for Federal laboratories. There is concern on the part of Federal laboratory scientific directors about the degree of autonomy and flexibility which they possess. We detect that paperwork, red tape, government regulations all mitigate against the establishment of a proper atmosphere for attracting good scientists and carrying out scientific research.

A laboratory director or project leader knows the capabilities of his staff and often has a better understanding of the details of problems than his superiors in Washington; thus, he is better able to marshal the resources of his laboratory to develop a meaningful research program. On the other hand he is perhaps less likely to be responsive to broad new opportunities and needs of the Nation which by their nature will change the focus of the laboratory. The problem is a perennial one and is not unique to oceanography. In matters of scientific research it is better to err on the side of decentralization, fully recognizing that within every agency there comes from time to time the need to focus on new and different problems and that until such redirection is accomplished a more centralized authority may be required. The panel encourages the Federal agencies responsible for these laboratories to take whatever steps are possible to minimize these constraints which scientists find so onerous.

The role of the Federal laboratories is critical not only to the missions of the Federal agencies but to the entire national marine science enterprise.

Recommendation:

Federal laboratories should be strengthened by moving in the direction of fewer but stronger laboratories adequately funded and staffed with even closer an affiliation with academic institutions. Steps should be taken to provide an atmosphere in these laboratories conducive to attracting first-rank scientists by providing the necessary flexibility at the scientific leadership level.

The conduct of basic marine science is dependent on the existence of a wide variety of technical support services usually provided by the Federal Government. Such support services are usually provided to meet many needs beyond those of research, such as the needs of those groups involved in ocean resource development, marine transportation, or the general public. Among the most important of the services for research are those dealing with mapping and charting, navigation and data management.

The panel has sought to identify the special needs of the research scientist for such services, to identify deficiencies that currently exist, and to make recommendations for their remedy.

I. MAPPING AND CHARTING

Maps and charts of the bathymetry, geophysics (gravity, magnetics) and geology (sediment characteristics, geologic structure, etc.) are necessary for the conduct of basic science. Such maps and charts, frequently prepared to serve other needs, such as navigation, resource exploration, or national security, have proven invaluable. Programs such as that recommended by the National Academy of Sciences[1] for systematic deep ocean surveys have had as their principal objective the needs of basic science. The more detailed the geologic chart, the more insight one gains into the nature of the geological processes. Thus, the effort that can be expended is almost unlimited, and it is necessary to derive criteria for determining the level of effort.

The panel has examined the recommendation of the Resources Panel on the mapping and charting needs for the resource development of the Continental Shelf and concurs with recommendations that bathymetric charts of 1:250,000 scale for the entire U.S. continental shelves and slopes be compiled within 15 to 20 years by the appropriate Federal agencies. We emphasize the importance of conducting gravity, magnetic, and sub-bottom reflection surveys simultaneously with the bathymetry, all keyed to the same navigational control.

We concur also with the recommendation concerning preparation of geological maps and three-dimensional analyses of the continental margins. We emphasize the importance of multi-disciplinary analyses of the cores that will be obtained from the 100 holes of 500 to 5,000 feet deep that are contemplated being drilled by the Federal agencies for the purposes of supplying the data for three-dimensional analyses. Besides mineralogical and geological analyses, such cores should also be studied for their paleontology and geochemistry.

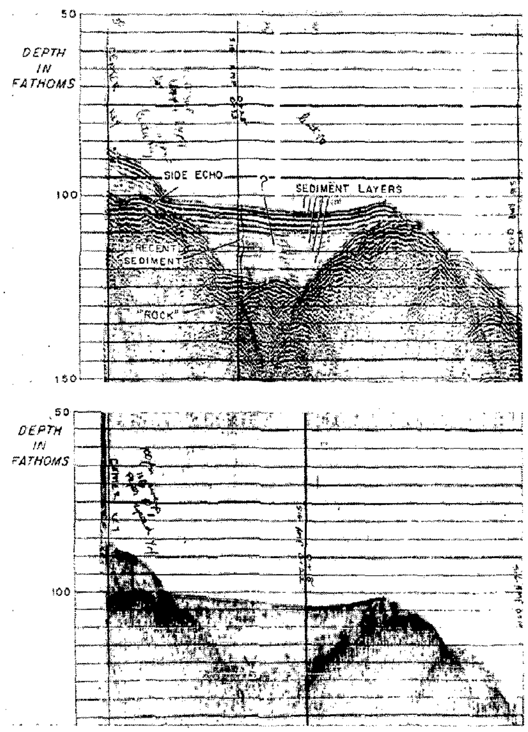

Figure 20. *Comparison of subsurface sediments simultaneously taken with conventional and updated bottom profilers indicate improvement possible with newer equipment. (Woods Hole Oceanographic Institution photo)*

The information they can furnish on past climates and sedimentation mechanisms is of high potential scientific value.

Most survey work has as its primary objective a purpose other than basic science, for example, navigation, national defense, mineral exploration.

[1] *Oceanography 1966,* National Academy of Sciences-National Research Council, Pub. No. 1492, 1967.

However, with a minimum of additional effort, mapping and charting undertaken for specific near-term objectives can, in many instances, satisfy certain needs of basic science.

The science community has used the forum of the National Academy of Sciences Committee on Oceanography to express its needs for mapping and charting. Progress in carrying forward many of that committee's recommendations has been painfully slow due to lack of adequate funding, both for ship operations and especially for shore based data processing.

There is a need for mechanisms whereby the Federal mapping and charting efforts are kept under frequent review by appropriate representative bodies of the scientific community, to insure that all mapping and charting efforts are responsive to the needs of the science. This recommendation is particularly timely in light of the U.S. proposal for an International Decade of Ocean Exploration which will involve extensive mapping and charting of the deep ocean as well as the Continental Shelf.

Recommendation:

The mapping and charting activities of the Federal Government should be made as responsive as possible to the needs of basic science and mechanisms should be established whereby mapping and charting operations of the Federal agencies can be reviewed to insure responsiveness to science needs.

II. NAVIGATION

Accurate all-weather navigation on the high seas is now possible through the Navy's Transit satellite system. Fixes are obtainable about every 90 minutes everywhere on the earth's surface. Economical, reliable receivers for the Transit system are not yet generally available, but the procurement efforts now under way through the Office of Naval Research are expected to remedy this situation in the near future. This important development will have far reaching results in increasing the ability to gather information pertinent to developing the seas' resources. We urge the Navy to proceed with all speed to make this system available to all and to encourage development of low-cost receivers and navigation devices to span between fixes.

The situation with regard to navigation over the continental shelves of the United States and in coastal waters beyond the capability of visual methods of position-fixing is not as favorable. Although the present LORAN systems are generally useful for the navigation of commercial shipping and aircraft, systems are available which will provide continuous position information of an accuracy of several tens of feet at ranges up to 200 nautical miles. Such a system is critically needed for basic research, for surveying, for navigation in congested shipping lanes, and for resource development and commercial fishing. We recommend, as did NASCO and PSAC before us, the establishment of such a system; the needs grow more critical each year.

A requirement also exists for the precise navigation of research submersibles. Absolute accuracy of position is required at least comparable to what one now achieves with LORAN-A, in conjunction with a system with a relative accuracy of a few tens of feet. It seems unlikely that available systems which depend on the receipt of electromagnetic transmission can be readily adapted for the use of small submersibles. Instead, they will require a system based on some other principle, most probably inertial or acoustic. The Navy's Deep Submergence Systems Project has such a development underway. Close liaison between that office and the U.S. scientific community is therefore recommended, with the aim of making Navy developments in this field available in the form of unclassified, moderately-priced devices for general civilian use.

Recommendation:

The Department of Transportation should proceed at high priority with the installation of a precise electronic navigational system sufficient to cover the entire coasts of the continental United States and Hawaii by the early 1970's and of Alaska and the Bering Sea by the late 1970's.

III. DATA CENTERS

Oceanographic data are collected at great expense and with great difficulty, not only by the Federal Government but also by private institutions and foreign governments. These data are indispensable for many research investigations.

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The basic science community looks to the Federal Government to establish and maintain appropriate data centers for the archival and retrieval to meet not only the needs of basic science but a wide spectrum of other uses as well.

Present systems do not meet the need for a coordinated system of data centers for archiving and retrieving oceanographic data. The efforts of the National Oceanographic Data Center, the Smithsonian Oceanographic Sorting Center, and the National Weather Records Center have barely been able to keep up with the present rate of acquisition, as well as the demands for retrieval.

A. National Oceanographic Data Center

The inability of the National Oceanographic Data Center to carry out its mission effectively has resulted from the peculiar nature of the Center, jointly funded by several Federal agencies with differing needs.

The Federal oceanographic funding situation in recent years has prevented government agencies from meeting the funding needs as expressed by the Director of the National Oceanographic Data Center and approved by its inter-agency advisory committee. Recently, the Navy, in an effort to provide more National Oceanographic Data Center support, offered to assume the entire fiscal responsibility for its work. Such a move will result in a Center less capable of dealing effectively in international data exchange. The Center, while it should be aware of naval requirements and geared to serve the Navy as well as other government agencies, should be located in a non-Defense agency, which should budget for and administer the funds necessary to maintain its basic operation in acquiring, coding, and storing data. Work performed for other agencies in the realm of data retrieval and analysis should be reimbursed from those agencies' appropriations in accordance with statutes and Federal practice. Similarly, costs of work undertaken for non-Federal agencies should be borne by requesting groups to the extent of payment of retrieval and reproduction costs.

The National Oceanographic Data Center's first mission was storing time-dependent data. Recently, it has become concerned with non-time dependent oceanic variables, such as bathymetry. The storage and retrieval of data that do not primarily vary with the time should not be concentrated in a single agency, but should be left in the hands of the principal gatherers of such data. Thus, the ocean charting activities of the Department of Commerce and the U.S. Navy should be the prime repository of worldwide bathymetric data, the portrayal of such data should take the form of published bathymetric charts at appropriate scales. In addition, the original data in the form of computer printouts should be available to the scientific community as the plotted smooth sheets have been made available in the past. Biological data relating to taxonomy should be concentrated with the specialists who are concerned with these aspects of science, and the role of the National Oceanographic Data Center should not extend past knowing of sources of information of this nature and maintaining liaison with the curators to facilitate the referral of inquiries.

The National Oceanographic Data Center should not undertake the processing of raw data. Such data should be processed by the originators and transmitted by them to the National Oceanographic Data Center in a form suitable for coding and analysis without the necessity of applying calibrations or instrumental corrections. The bathythermograph processing function should be returned to the Navy and the other users of bathythermographs.

The National Oceanographic Data Center is not now involved in the management of real time ocean monitoring and prediction systems and should not become so involved in the future. Its primary function is the acquisition of historical data.

B. National Weather Records Center

Unlike the National Oceanographic Data Center, the National Weather Records Center has been in existence for half a century. Its primary mission is to archive the national and international weather records. Its marine functions include the archiving and retrieval of all ocean weather, sea state, and sea surface temperature data. It is funded by the Department of Commerce and performs work for other agencies on a reimbursable basis; it also provides, at cost, retrieval and reproduction for needs of all non-Federal users. Large parts of its marine programs are supported by the Navy under reimbursable agreements. The National Weather

Records Center has suffered over the years from the same financial constrictions as the National Oceanographic Data Center and is unable to fully meet the growing needs for marine data.

C. Smithsonian Oceanographic Sorting Center

The Smithsonian Oceanographic Sorting Center is a service organization developed in response to the need for expediting the analysis of biological and geological samples. Plankton samples, for example, may include representatives of more than fifty major animal groups, each group requiring examination by specialists to assure proper analysis. The initial sorting, however, may be done by technician level personnel. The sorted collections are shipped to specialists located throughout the world. This permits the effective use of the small number of skilled taxonomists. The Center is supported both by direct appropriation and through contracts with several Federal agencies, including Department of the Interior, National Science Foundation, and the Office of Naval Research. Present funding levels permit the sorting of approximately 35 per cent of the samples received.

The parent organization of the Sorting Center, the Smithsonian Institution, fulfills a vital national need, both as a reference collection of natural history specimens and as a research center. Current legislation (Title 20, Section 59, U.S.C.) requires that all biological and geological specimens obtained with Federal funds be turned over eventually to the Smithsonian Institution. The Smithsonian Institution, however, is not presently equipped to handle properly the vast quantities of marine material that would be left at its doorstep were this requirement of law to be carried out literally. At present, the Smithsonian only exercises this authority in cases where it believes collections will be lost. The panel concurs in this interpretation of the law.

On the other hand, biological and geological investigations carried on by mission oriented agencies, universities and oceanographic institutions frequently result in the collection of large and diverse samples. In many instances only a small portion of the collection is actually studied, for example, only the fish eggs and larvae may be counted, identified, and subjected to appropriate analyses. The remaining portions of the sample, which can make up more than 90 per cent of the collection, may remain unsorted. This residue, however, is a valuable library for future reference. Judgment of the impact of environmental change and determination of long term trends, depends upon the availability of collections made either prior to the change or over long periods of time. Adequate storage facilities and appropriate curatorial responsibility must be assigned to assure that valuable materials will not be lost. Costs of maintenance are small relative to the original costs of making the collections and should be considered as part of the operating expense of the national oceanographic program. The panel believes that the Smithsonian Institution is the proper agency to perform this function. The organization that collected the material should be encouraged to make it available to the Smithsonian at Smithsonian expense.

D. A Coordinated System of Data Centers

The needs of basic science for adequate data centers will require that the Federal Government insure that the activities of its principal marine data centers operate as part of a coordinated system of data centers. Such a coordinated system is necessary to permit scientists to request and receive data which they need from the historical archives in an expeditious manner. A scientist studying a problem in marine fisheries may require not only biological information but information for all the marine and atmospheric physical conditions at specified geographical locations and for specified periods of time. At the present time, it is a lengthy and difficult process to obtain such data from the present data centers.

Recommendation:

The National Oceanographic Data Center, National Weather Records Center, and the Smithsonian Oceanographic Sorting Center should be adequately supported with funds to enable them to keep up with the growing volume of marine data and to take advantage of modern achiving and retrieval technology. This will permit the establishment of a closely linked coordinated system of marine data centers. The National Oceanographic

Data Center should be organizationally lodged in a non-Defense agency to permit it to meet the needs of the entire oceanographic community more effectively. The basic operations of the National Oceanographic Data Center should be funded b the agency in which it is lodged and wor undertaken for other agencies should be on reimbursable basis.

In reviewing the status of marine science in the United States, the panel sought to determine whether Federal or international organizational arrangements were meeting needs. We sought to identify particular organizational conditions which in themselves represented obstacles to the conduct of the marine science effort. We found that it was impossible to separate clearly organizational issues from funding issues. However, we have attempted to examine separately the structural organization problems from the more general funding problem.

I. STRUCTURAL ISSUES IN FEDERAL ORGANIZATIONS

Most scientists interviewed were by and large satisfied with the present institutional arrangements for the support of basic science. The principal structural problems detected involved difficulties within the present structure of acquiring support for facilities, large interdisciplinary programs, and engineering development.

The Office of Naval Research is generally credited with a major role in developing the present level of competence and vigor in the Nation's oceanographic program. It pioneered in the support of a variety of programs, especially in providing many kinds of large facilities, such as ships and laboratories, in the establishment of institutional grants, and in block funding for ships.

The Navy, through the Office of Naval Research and the Naval Ships Systems Command (formerly Bureau of Ships), has been able to fund shore facilities only to a limited extent, although it has been successful in providing floating facilities, such as the research submersible *Alvin*, the stable floating platform and a series of conventional research vessels such as FLIP, the *R. V. Acona*, and a series of AGOR's.[1] The third generation of AGOR's, now under construction, has been designed as the result of a close and valuable collaboration between the user research agencies and the Navy's own highly competent ship design staff.[2]

Since 1958, the National Science Foundation has performed a vital role in the support of basic research in the marine sciences at research institutions across the country. The Foundation does not operate in-house laboratories. However, it has encouraged the use of ships as national facilities by funding the *R. V. Eltanin* for work in Antarctica and the *R. V. Anton Brunn* for the International Indian Ocean Expedition.

The support of individual scientists working on specific projects is what the National Science Foundation does best. However, over the years it has become necessary for the National Science Foundation to pick up the burden of such essential support as block funding for oceanographic research ships and facility support for marine laboratories.

This program of the Foundation has been highly successful within the limited appropriations available. These two Federal agencies have provided the bulk of the large facility support for academic institutions. Facility support for in-house laboratories of the Federal agencies has been much more consistent. Generally, Federal laboratories have inadequate manpower and funds to use existing facilities to the maximum.

The new requirements of the marine science laboratories for major facility support could be handled through the Navy and National Science Foundation if adequate funds for these purposes were provided them. While the panel sees no difficulties with such a procedure for the Office of Naval Research, it does have certain concerns with regard to such a procedure for the National Science Foundation; the National Science Foundation may become so committed to the long-range support of capital facilities and institutional operations that its flexibility to support new programs and young scientists would be limited.

If we are to mount the kinds of programs discussed in this report, some better means of

[1] Auxiliary General Oceanographic Research.

[2] *New Concepts Applied to Research Ship Design*, Reed, Sarchin and Leiby, Chesapeake Section, Society of Naval Architects and Marine Engineers, May 16, 1968.

providing long-range institutional and facility support must be found.

Recommendation:

The major civil responsibility for providing institutional and facility support should be invested in the new agency recommended by the Commission. The National Science Foundation should be relieved of this responsibility. The Office of Naval Research should continue to provide the kinds of support it has in the past. Other Federal agencies should provide limited institutional and facility support.

II. STRUCTURAL ISSUES IN INTERNATIONAL ORGANIZATIONS

In general, the present governmental and non-governmental international organizations which enable nations to collaborate on marine science problems have served well. The principal intergovernmental organization is the Intergovernmental Oceanographic Commission of United Nations Education, Scientific, and Cultural Organization founded in 1961. Other intergovernmental bodies, such as the World Meteorological Organization and the Food and Agricultural Organization, are involved in certain science problems. The principal non-governmental international body which provides a forum for marine science is the Scientific Committee on Oceanic Research of the International Council of Scientific Unions and the International Union of Geodesy and Geophysics.

Marine science affairs will ultimately require an intergovernmental body at the treaty level, perhaps as a separate specialized agency of the United Nations. Insofar as the needs of basic science are concerned, however, the Intergovernmental Oceanographic Commission presently has the breadth of charter required and provides a suitable intergovernmental forum. The Intergovernmental Oceanographic Commission, however, requires strengthening. It now has no control of its own budget. Its secretariat is too small to undertake the tasks required of it. It has problems of coordination and cooperation with other international organizations such as the World Meteorological Organization and Food and Agricultural Organization, although increased collaborative effort between the three organizations has improved markedly in recent years.

We hesitate to make recommendations with respect to organizations within the International Council of Scientific Unions. The basic issue to be confronted involves whether there shall be a separate union, dealing with all aspects of marine science or whether marine science should be strengthened within the existing unions. The International Association of Physical Oceanography at the 14th General Assembly of the International Union of Geology and Geophysics in Berne, October 1967, passed the following resolution:

Resolution No. 10

The International Association of Physical Oceanography; cognizant of the growing need for closer, inter-disciplinary working contacts in the field of marine sciences; requests the Executive Committee to study, in collaboration with other international organizations, interested in oceanography, and to report to the XV General Assembly of the Association on the desirability and feasibility of establishing an International Union of Marine Sciences (IUMS) which would contain associations dealing with sciences concerned with the ocean, that is; with marine geophysics and geology, marine chemistry, physical and meteorological oceanography, and marine biology; resolves to convene, if practicable, its XV General Assembly jointly with the Scientific Committee on Oceanic Research (of ICSU), with the International Association of Biological Oceanography (of the IUBS), with the Commission on Marine Geology (of IUGS) and with IAMAP, in particular those sections interested in air-sea interaction problems.

The organizational problem is complex and the panel leaves the answer for the best way to proceed in the future to the scientific groups involved. However, we do believe that the increased marine science activity, the proposed strengthening of marine affairs within the UN, and in particular the proposed International Decade of Ocean Exploration requires some consolidation or at least better coordination within the family of scientific unions.

Recommendation:

Immediate steps should be taken to strengthen the Intergovernmental Oceanic Commission as the principal intergovernmental forum for marine

science and to facilitate its collaborative efforts with other international intergovernmental groups. As an ultimate goal, a separate treaty organization should be established within the United Nations system for marine science and other suitable marine applications.

III. FUNDING SUPPORT

In this section, we are concerned with the amount of funding required to carry forward the marine science program recommended in this report. We are concerned with some of the principles that we believe should guide the funding process.

The panel urges that every Federal agency which is responsible for marine research and maintains in-house capability should, for its own health, vigor, and flexibility as well as for that of all National marine science, strike a reasonable balance between in-house and out-of-house basic research. The ratio of in-house to out-of-house support of basic marine science will, of course, vary from agency to agency. A target of 50 per cent in-house and 50 per cent out-of-house is reasonable for basic research although it is recognized that this ratio will be a function of agency needs as well as agency programs. The programs should not be in competition with each other for the same funds. The National Academy of Science Committee on Oceanography in its report *Oceanography 1966,*[3] has set forth a rationale which it feels could be adopted by Federal agencies in considering the split between "discipline" oriented and "problem" oriented research. This rationale seems worthwhile and it is commended to Federal agencies for their consideration.

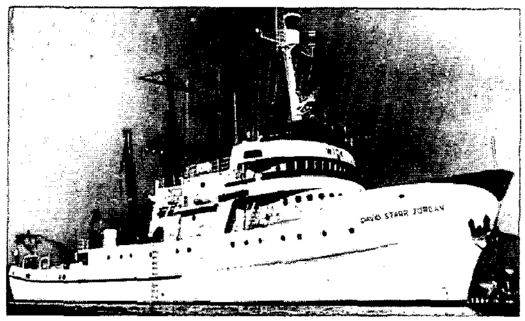
Within the new agency recommended by the Commission there should be an office whose primary responsibility is the funding of institutional grants, facility support, and engineering development recommended in this report.

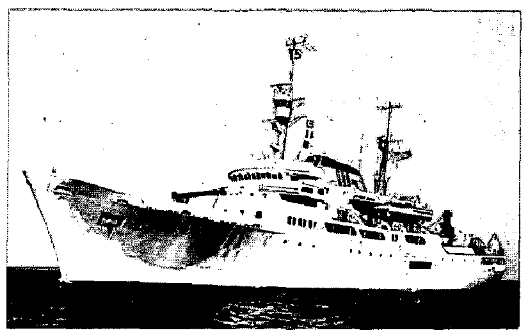
The specific programs recommended in this report clearly indicate that an increase of basic science funding is required to achieve the essential base of knowledge about the ocean environment for presently anticipated and future unanticipated uses.

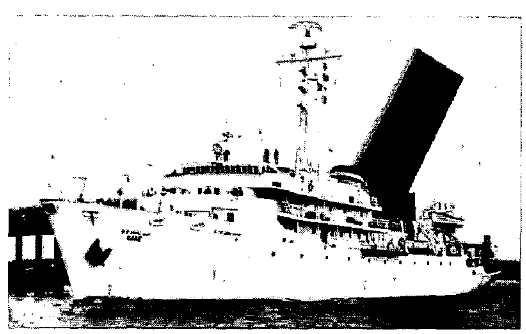
[3]*Oceanography 1966*, National Academy of Sciences-National Research Council, Pub. No. 1492, 1967.

Figure 21. *Federal oceanographic research vessels*

Coast Guard–ocean station vessel


Bureau of Commercial Fisheries–fisheries research vessel


Environmental Science Services Administration–U.S. Coast & Geodetic Survey oceanographic research vessel


U.S. Navy–naval research vessel

While it is difficult to assess the exact cost of this expanded effort, an analysis of the programs indicate that incremental funding for the 1970's should show an annual increased spending level of approximately $200 million. Forty per cent of this increased funding would be for capital and operating requirements of the university-National laboratories, 10 per cent for the coastal laboratories, 15 per cent for in-house Government laboratories, and the remaining 35 per cent for increased Federal funding of other out-of-house research by the various agencies.

Recommendation:

The basic science effort of this Nation must be maintained and expanded to encompass the program described in this report. To achieve this an incremental increase of approximately 20 per cent per year for operating and capital expenditures should be maintained until the current basic science funding base has increased by $200 million annually.

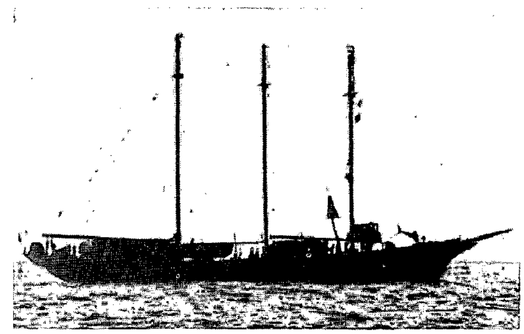
The panel encountered repeatedly the problem of ship funding, both for capital expenditures and operation. We have recommended a variety of laboratories necessary to conduct the National effort.

This suggests a variety of management and funding arrangements. We do not concur with the President's Science Advisory Committee recommendation that all fleets be regional fleets.[4] Many institutions can operate their own vessels and this practice should continue. We do not even suggest that all ocean-going research vessels should be operated by university-National laboratories. Although the university-National laboratory can be expected to provide ship facilities for many scientists from non-ship operating institutions, we do not think this is the only answer. Operations such as those conducted by Duke University with *R. V. Eastward* and Scripps Institution of Oceanography with *R. V. Alpha Helix* suggest that there are other ways to provide successfully for the needs of the research community.

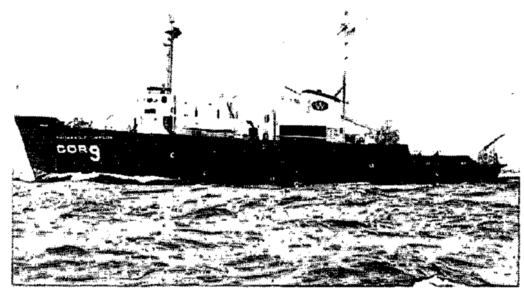
When a laboratory is large enough to use a research vessel efficiently, it is better that the

[4] *Effective Use of the Sea,* Report of the Panel on Oceanography, President's Science Advisory Committee, 1966.

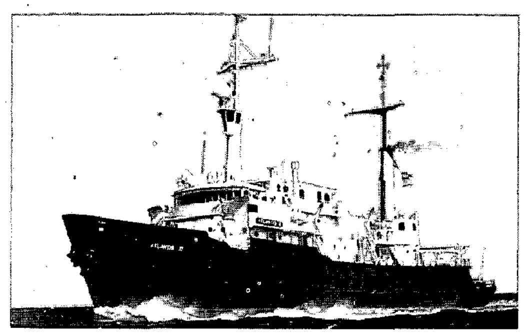
Figure 22. *University research vessels*



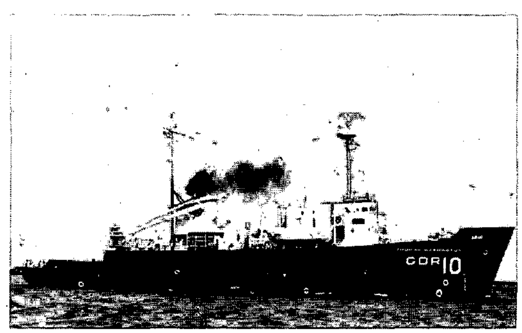
Lamont Geological Observatory–Columbia University research vessel



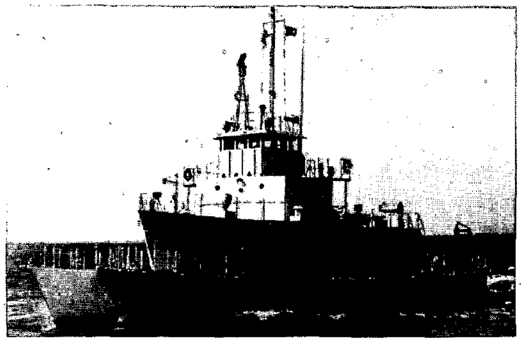
University of Washington research vessel



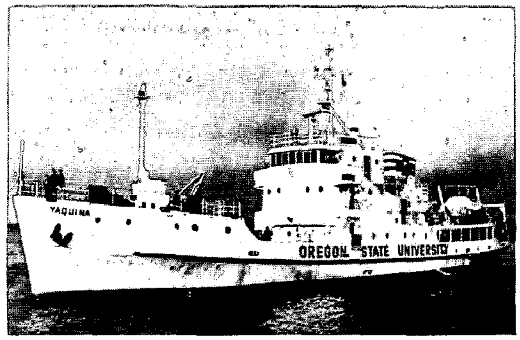
Woods Hole Oceanographic Institution research vessel

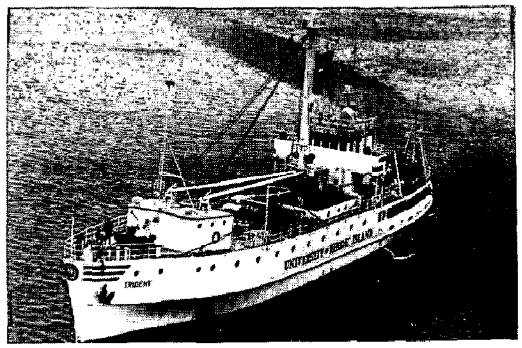


Scripps Institution of Oceanography research vessel



Chesapeake Bay Institute, Johns Hopkins University--research catamaran vessel





University of Rhode Island research vessel

vessel be under the control of that laboratory than operated as part of a regional fleet. Ship operations are a major part of the costs of large research institutions, but although ship operation costs have increased in recent years, the percentages have not. The total cost of ship operations at the major oceanographic laboratories varies between 20 and 30 per cent of the total institutional budget.[5]

The many intangible factors that determine successful sea operations are not all easily identifiable, but one of the most important is familiarity with the facility. A research vessel is a laboratory. Usually it is difficult for an experimental scientist to go to another university as a visiting professor, walk into a new laboratory, and continue his research program at the same level of efficiency. The new laboratory will be lacking certain facilities or pieces of equipment that he has at home. It takes time to learn what can be done and how to get things done.

Scientists within a laboratory who control a vessel can often modify it so that it can do new kinds of experimental work. In a very real way, they design programs about the facilities of a given vessel. They know what they can and cannot do on any given ship. It would not be as easy with a regional fleet. We believe that most of the advances in the state of the art, in terms of what one can learn at sea, will continue to be made by those persons working at oceanographic laboratories. Oceanographers are no different from other scientists in that, other things being equal, they tend to gravitate to the institutions with the best facilities.

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[5] *The Role of Academic Institutions in the Development of Marine Resources and Technology*, Report of the Council of Oceanographic Laboratory Directors, Sept. 12, 1967.

The Federal agencies actively engaged in oceanographic missions usually publish an annual or biannual report on their research activities. A bibliography of these reports by agency is as follows:

ESSA – *Science & Engineering – July 13, 1965 to June 30, 1967,* U.S. Department of Commerce, Environmental Science Services Administration, April 1968, U.S. Government Printing Office.

NAVY – *The Ocean Science Program of the U.S. Navy, Accomplishments and Projects,* Office of the Oceanographer of the Navy, June 1967, U.S. Government Printing Office.

N.S.F. – *National Science Foundation Annual Report 1968,* NSF 69-1, U.S. Government Printing Office; *National Science Foundation List of Grants and Awards 1968,* NSF 69-2, U.S. Government Printing Office.

Coast Guard – U.S. Coast Guard Oceanographic Reports, USCG Publication Series 373, especially *Annual Report of Oceanographic Activities – 1968,* Publication 373-18, U.S. Government Printing Office.

Atomic Energy Commission – *The Atom and the Ocean,* U.S. Atomic Energy Commission, January 1968, available from AEC, P.O. Box 62, Oak Ridge, Tennessee 37830; *Marine Sciences Research,* March 1966, Division of Biology & Medicine AEC, U.S. Government Printing Office.

Smithsonian Institution – *Smithsonian Year – 1968,* available from Smithsonian Institution, Washington, D.C.

Department of Interior – *Geological Survey Research – 1967,* G.S. Professional Paper 575-A-1967, U.S. Government Printing Office; *Progress in Sport Fishing Research – 1967,* Fish and Wildlife Service Resource Publication 64, May 1968, U.S. Government Printing Office; *Bureau of Commercial Fisheries Federal Aid Program Activities – 1968,* BCF Circular 293, U.S. Government Printing Office.

Current programs of agencies not publishing specific reports are covered in *National Marine Sciences Program,* Part 1, Hearings before the Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, House of Representatives, 90th Congress, 1st Session, Serial No. 90-19, U.S. Government Printing Office.

Hearing Schedule

Date	*City*	*Host*
Oct. 9-12, 1967	Washington, D.C.	
Nov. 6-7, 1967	Boston	Massachusetts Institute of Technology
Nov. 8-9, 1967	New York	Ford Foundation
Dec. 4, 1967	Chicago	Federal Water Pollution Control Administration
Dec. 5-6, 1967	Seattle	University of Washington
Dec. 7-8, 1967	La Jolla	Scripps Institution of Oceanography
Jan. 10-11, 1968	Houston	Gulf Universities Research Corporation
Jan. 12-13, 1968	Miami	University of Miami

Persons Appearing at Panel Hearings

Elbert Ahlstrom, Senior Scientist, Bureau of Commercial Fisheries, Ocean Research Laboratory, Stanford, California

Dick Bader, Associate Director, Institute of Marine Science, University of Miami, Miami, Florida

L. Bajournas, Director, Great Lakes Research Center, Detroit, Michigan

George F. Beardsley, Jr., Assistant Professor, Physical Oceanography, Oregon State University, Corvallis, Oregon

Harry J. Bennett, Professor of Zoology, Louisiana State University, Baton Rouge, Louisiana

Leo Beranek, President, Bolt, Beranek & Newman, Cambridge, Massachusetts

Donald E. Bevan, Associate Dean, College of Fisheries, University of Washington, Seattle, Washington

F. G. Blake, Senior Research Scientist, Chevron Research Co., La Habra, California

C. Bookhout, Director, Duke University Marine Laboratory, Beaufort, North Carolina

Capt. J.D.W. Borop, USN, Director, U.S. Navy Mine Defense Laboratory, Panama City, Florida

Ronald A. Breslow, Executive Assistant to Commissioner, New Jersey State Department of Conservation and Economic Development, Trenton, New Jersey

Douglas L. Brooks, President, Travelers Research Center, Hartford, Connecticut

Herbert Bruce, Assistant Laboratory Director, Bureau of Commercial Fisheries Auke Bay Biological Laboratory, Auke Bay, Alaska

John C. Bryson, Executive Director, Delaware Water & Air Resources Commission, Dover, Delaware

Horace R. Byers, Dean, College of Geosciences, Texas A&M University, College Station, Texas

Stanley A. Cain, Assistant Secretary of the Interior for Fisheries and Wildlife, Washington, D.C.

A. J. Carsola, Manager, Oceanics Division, Lockheed, San Diego, California

David C. Chandler, Director, Great Lakes Research Division, University of Michigan, Ann Arbor, Michigan

Joe S. Creager, Associate Dean, Arts and Sciences, University of Washington, Seattle, Washington

Franklin C. Daiber, Acting Director, Marine Laboratories, University of Delaware, Newark, Delaware

David Dean, Director, Darling Center, University of Maine, Walpole, Maine

Robert G. Dean, Chairman, Department of Coastal and Oceanographic Engineering, University of Florida, Gainesville, Florida

John De Noyer, Advanced Research Projects Agency, Department of Defense, Washington, D.C.

John Emmick, Vice President, Foundation for Oceanographic Research and Education, Port Canaveral, Florida

R. G. Fleagle, Chairman, Department of Atmospheric Sciences, University of Washington, Seattle, Washington

Glenn A. Flittner, Acting Assistant Laboratory Director, Fishery-Oceanography Center, Bureau of Commercial Fisheries, La Jolla, California

Harry W. Freeman, Professor of Biology, College of Charleston, Charleston, North Carolina

Hugo Freudenthal, Chairman, Graduate Department of Marine Science, Long Island University, East Meadow, New York

Herbert F. Frolander, Acting Chairman, Department of Oceanography, Oregon State University, Corvallis, Oregon

Paul M. Fye, Director, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

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Perry W. Gilbert, Executive Director, Mote Marine Laboratory, Sarasota, Florida, and Professor, Cornell University

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Rear Admiral O.D. Waters, Jr., Oceanographer of the Navy, Washington, D.C.

J. Wayne, Associate Director, Lamont Geological Observatory, Palisades, New York

Edward Wenk, Jr., Executive Secretary, National Council on Marine Resources and Engineering Development, Washington, D.C.

Jerome Wiesner, Provost, Massachusetts Institute of Technology, Cambridge, Massachusetts

Frederick C. Wilbour, Director, Division of Marine Fisheries, Massachusetts Department of Natural Resources, Boston, Massachusetts

Adm. John M. Will, Vice President, American Export-Isbrandtsen Lines, New York, New York

Donald E. Wohlschlag, Director, Marine Sciences Institute, University of Texas, Port Aransas, Texas

Paul Wolff, Captain, USN, Fleet Numerical Weather Facility, Monterey, California

Brig. General H. G. Woodbury, Jr., Director of Civil Works, Office of the Chief of Engineers, U.S. Army, Washington, D.C.

G. P. Woollard, Director, University of Hawaii, Honolulu, Hawaii

W. S. Wooster, Professor, Scripps Institution of Oceanography, La Jolla, California

William V. Wright, Jr., Director of Science and Engineering, Environmental Science Services Administration, Washington, D.C.

Jacques S. Zaneveld, Director, Oceanographic Institute, Old Dominion College, Norfolk, Virginia

Figure 1. *Hurricane driving sea against North Bayshore retaining wall, Biscayne Bay, Miami, Sept. 21, 1964. (ESSA photo)*

Part II

Report of the Panel
on Environmental Monitoring

Contents

Among the charges to the Panel on Environmental Monitoring by the Commission was the examination of those problems in which the oceans are but one element of the complex interacting geophysical system. The panel first charted its course of action at a three-day meeting in August 1967 at the University of Rhode Island. To avail itself of all possible information bearing on its problems nation-wide hearings were scheduled, jointly with the Panel on Basic Science. The first hearings were held in Washington, D.C., during the period Oct. 9-12, 1967; all Federal agencies conducting ocean-related programs were given an opportunity to describe their present activities and plans for the future. Representatives of the following agencies participated:

Department of the Navy
Corps of Engineers, Department of the Army
Advanced Research Projects Agency
Department of the Interior
National Aeronautics and Space Administration
Department of Commerce
Department of Transportation
Department of Health, Education, and Welfare
National Science Foundation
Atomic Energy Commission
Smithsonian Institution

At the conclusion of the Washington hearings, the panel initiated field hearings; witnesses representing the university community, industry, Federal field activities, and State and local governments were heard. A schedule of the hearings and a complete list of the more-than-one-hundred witnesses appears in Appendix A.

The panel members were assisted throughout their deliberations by the following consultants:

S. Fred Singer, Deputy Assistant Secretary for Scientific Programs, Department of the Interior
Karl K. Turekian, Professor of Geology and Geophysics, Yale University
Henry W. Menard, Professor of Oceanography, Scripps Institution of Oceanography, LaJolla, California
Walter H. Munk, Professor and Associate Director, Institute of Geophysics and Planetary Physics, University of California

The panel supplemented its own information-gathering activities by making extensive use of earlier surveys of the field, particularly these recent reports:

Committee on Oceanography, National Academy of Sciences-National Research Council, *Oceanography 1960 to 1970,* NAS-NRC, Washington, D.C. (1959) (out of print).
Committee on Oceanography, National Academy of Sciences-National Research Council, *Oceanography 1966,* Achievements and Opportunities, NAS-NRC, Washington, D.C. (1967).
Panel on Oceanography, President's Science Advisory Committee, *Effective Use of the Sea,* Washington, D.C. (1966).

The panel was also in a position to review, via close liaison with the National Council on Marine Resources and Engineering Development, all current planning activities of the Federal agencies participating in the Nation's oceanographic program. In particular, a Commission representative participated in the meetings of the Council's Committee on Ocean Exploration and Environmental Services, and the panel reviewed the report prepared by the Committee:

National Council on Marine Resources and Engineering Development, Committee on Ocean Exploration and Environmental Services, *Federal Plan for Marine Environmental Prediction,* Washington, D.C., July 1, 1968.

Continuing discussions were held during the preparation of this report with many private citizens as well as Government representatives. Representatives of the Navy, the Coast Guard, the Environmental Science Services Administration, the Maritime Administration, The National Aeronautics and Space Administration, and the Bureau of Commercial Fisheries, were especially helpful.

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A major review of the panel's report was conducted by panel members, consultants, and these other reviewers:

Milner B. Schaefer, Science Advisor to the Secretary, Department of the Interior.

Roger Revelle, Director, Center for Population Studies, School of Public Health, Harvard University.

John Calhoun, Jr., Executive Director, Gulf Universities Research Corporation, Chairman, National Academy of Sciences Committee on Oceanography.

The panel, while heartily acknowledging the generous assistance of its consultants and reviewers, does, of course, consider all findings and recommendations the responsibility of the panel members alone.

Finally, we must state that this report could not have been written without the dedicated assistance of the panel's Executive Secretary, Leon S. Pocinki, to whom we wish to express our great appreciation.

John A. Knauss, *Chairman*
Frank C. Di Luzio
Leon Jaworski
Robert M. White

I. THE NEED

New requirements for real time monitoring of the ocean and atmosphere, and predicting their changes, make it vital to the National interest that we take firm steps toward the establishment of a comprehensive global oceanographic monitoring and prediction system, in concert with other nations. The potential benefits to all marine activities, as well as land-based activities, are substantial—in improved warning of ocean and weather hazards to life and property, support to marine transportation and resource development, and enhancement of National security.

—The air, sea, and land are inseparable parts of a single geophysical system. The observation, communication, and data processing systems—and their supporting technologies—for the atmosphere and the oceans have many features in common. Winds generate sea surface waves and drive the ocean's currents. Hurricanes are generated at sea and draw their energy from the sea. To predict these phenomena we must understand the earth-ocean-atmosphere interactions.

—Sensors aboard one platform can collect data in both the air and the sea; communications systems can be shared. A viable oceanographic monitoring and prediction system must be planned within a comprehensive environmental system which includes the atmosphere and certain aspects of the solid earth.

Recommendation:

The Nation's oceanographic monitoring and prediction activities should be integrated with the existing National weather system (as well as certain aspects of the solid earth) to provide a single comprehensive system, which the panel has identified as the National Environmental Monitoring and Prediction System (NEMPS).

Provisions should be made for:

—Immediate improvements in the present system through the increased use of equipment which is already available and which can be deployed at modest cost.

—Development of new technology to improve data acquisition, communications, and processing on a global basis, with systems studies proceeding in parallel.

—Research to remove present scientific limitations on our ability to predict the state of the ocean, its biota, and the atmosphere.

—A single civil system to meet common needs for environmental observations and forecasts of all agencies and users.

—Specialized systems to meet needs of the Department of Defense and other agencies, planned and coordinated with the common system.

The panel proposes that the Nation establish as a target the full implementation of a modernized and expanded global environmental monitoring and prediction system by 1980.

—The first half of the next decade should be devoted to immediate improvements in the system which could be introduced at low cost with existing technology, and to the development of new technology which will be necessary to realize the full range of possibilities.

—By 1975 the Nation should be in position to relate the potential improvement due to deployment of new technology to associated costs.

—By 1980 the next-generation system should be in place to provide adequate data coverage and services to meet the National needs.

II. NEAR-TERM IMPROVEMENTS IN THE MARINE ENVIRONMENTAL PREDICTION SYSTEM

Most oceanographic and marine weather prediction programs rely on data communications, processing, and dissemination provided by systems operated primarily by the Department of Defense (Navy and Air Force), Department of Commerce

(ESSA), and Department of Transportation (FAA and Coast Guard). A description of the way in which the system operates today is presented in Chapter 3.

A. Ocean Structure Prediction

Analysis and prediction of sea surface conditions are now limited by the scarcity of surface ocean and weather observations. Similarly, the analysis of ocean thermal structure is data-limited. Present ship-of-opportunity programs can be expanded at relatively low cost. Needed data could be provided by additional expendable bathythermograph soundings from such ships. Administrative mechanisms are already established. Improved prediction of the sea and weather conditions in coastal areas and the Gulf of Mexico could be realized by more extensive instrumentation of offshore platforms.

Recommendation:

The ship-of-opportunity program should be expanded immediately to provide more surface ocean and weather reports, additional ocean temperature structure data, and more wind soundings. Ships operating in regions not covered by major merchant vessel trade routes should be included. Additional instrumentation should be placed on offshore platforms.

B. Tsunami Warnings

The Tsunami Warning System's ability to forecast tsunami arrival times at Pacific Ocean locations is satisfactory, but tsunami runup forecasts are often grossly in error. To improve system performance we make the following recommendation:

Recommendation:

Steps should be taken to expand present tide and seismic monitoring stations in the Pacific basin. International communications from South America and the Southwest Pacific should be improved. Additional research on tsunami generation and runup problems should be instituted.

C. Hurricane Warnings

The hurricane warning system performs adequately within its present constraints. Forecasts of hurricane development and motion, and the hurricane-generated storm surge are, however, inadequate. More extensive hurricane data are needed to test mathematical models.

Recommendation:

The Hurricane Warning Service requires expanded data networks. This Service should be accorded high priority to take advantage of the latest technical and operational developments. Additional research is needed to improve our capability to forecast hurricane development and motion.

D. Sea-Ice Forecasting

The Navy and Coast Guard each operate sea-ice forecasting programs; ESSA operates a sea-ice mapping program. Ice forecasting has achieved a useful level of accuracy but is severely limited by lack of observational data and basic knowledge.

Recommendation:

Research efforts to improve sea-ice forecasting should be expanded; efforts in remote sensing of glacial and sea ice, especially in sensors that can penetrate clouds, are encouraged. Further basic research in energy transfer through the air-ice-water media to yield improved models of formation, growth, drift, deformation, and disintegration of different ice types is required.

III. NEW TECHNOLOGY DEVELOPMENT PROGRAMS

Many technological developments are at a stage where they can provide a significant improvement in our ability to observe the environment, to transmit and process the observed data, and to retransmit forecasts. The panel has noted progress in the development of new data-collection platforms: satellites and buoys. Remote sensing of the environment from these platforms, as well as aircraft, show great potential. New developments should be pursued to the point of field tests to permit a rational assessment of their future operational utility. Our position is summarized in the following recommendation:

Recommendation:

The Nation must push forward with a comprehensive and diversified program for the development of new technologies to monitor the global marine environment. Such a program is the key to maintaining adequate surveillance over our total marine environment.

A. Buoys

Buoy system technology offers a promising approach to the collection of oceanographic and meteorological data in remote ocean areas. Cost estimates for proposed full-scale operational buoy systems indicate the need for adequate field testing before final deployment decisions are made. Experimental buoy systems could be used to advance our understanding of major scientific problems as well as provide tests of buoy hardware.

Recommendation:

The National Data Buoy Development Program should be pursued vigorously. The program should provide for tests of alternative buoy hardware configurations, and different network spacings before a commitment is made to a major operational system; many of these tests can be conducted in support of major oceanographic research efforts.

B. Aircraft

Aircraft have been used effectively to collect meteorological data, measure sea-surface temperatures, launch expendable bathythermographs, and collect sea-state data.

Recommendation:

The oceanographic aircraft role in an operational environmental monitoring system must be reviewed. Aircraft operated for other missions by various Federal agencies should be instrumented to collect oceanographic data.

C. Earth-Orbiting Satellite

Results from the TIROS, NIMBUS, and ESSA satellites indicate their potential for regular global synoptic coverage of surface ocean conditions. Sensors now available or in advanced development can provide routine sea-surface temperature measurements, ice mapping, and estimates of sea-surface "roughness." The satellite can serve as a communications link for the interrogation of ocean platforms and transmission of the data to central processing facilities.

Recommendation:

NASA development of satellite-borne oceanographic sensors, of techniques for the location of platforms, and of transmission of data from platforms should continue. Plans for early use of oceanographic sensors on board operational satellites should be pursued vigorously.

IV. RESEARCH PROGRAM

While environmental monitoring is technology-limited, environmental prediction is seriously limited by a lack of basic understanding. To remove the principal scientific limitations the panel makes the following recommendation:

Recommendation:

Intensive research efforts should be mounted to provide the necessary understanding of oceanographic processes in:

–Sea-air interaction

–Scales of motion

–Dynamics of ocean currents

–Biological-physical environmental relationships.

V. ORGANIZATION

A. Agency Responsibility for NEMPS

Four Federal agencies are principally involved in the provision of marine environmental monitoring and prediction services: Department of Defense (Navy, Air Force), Department of Transportation (Coast Guard and FAA), Department of

Commerce (Environmental Science Services Administration), and Department of Interior (Bureau of Commercial Fisheries). Present coordination mechanisms do not provide for adequate planning, management, and design of a comprehensive marine environmental monitoring and prediction system. The panel has taken the position that oceanographic and atmospheric monitoring and prediction programs must be planned, implemented, and conducted jointly.

We find that, to ensure responsiveness to military requirements—as well as to satisfy civil needs—suitably coordinated military and civil systems must be maintained. Responsibility for the civil system should be focused in one agency, for planning, funding, and management of common system elements. Data acquisition and communications should be shared and pooled operations; civil and military data processing and forecasting centers should operate, essentially in parallel, to ensure responsiveness to specialized requirements and also for back-up and increased reliability.

Recommendation:

Activities in the National Environmental Monitoring and Prediction System serving common civil and military interests should be consolidated in one Federal agency; specialized military programs should be retained in the Department of Defense. Civil and military environmental monitoring and prediction systems should develop within the following guidelines:

—A common, shared data acquisition network

—A common, shared communications network, except where military security requires separate systems

—Independent, parallel data processing and forecasting facilities

—Independent, specialized data and forecast dissemination sub-systems.

B. Data Storage and Retrieval

The present system for storage and retrieval of oceanographic information is unsatisfactory. Unless significant changes are made, it will not be able to handle the vast volumes of data which the NEMPS will generate. The National Oceanographic Data Center, which is responsible for certain categories of oceanographic data storage and retrieval, has not been able to keep pace with growing needs. It is funded under multi-agency arrangements and is not assigned as a major mission to any one agency. Environmental data is also archived at other centers. For example, meteorological data as well as surface ocean data are archived at ESSA's National Weather Records Center.

Recommendation:

A coordinated system of oceanographic and other environmental data centers should be established. The NODC should be transferred to the civil agency responsible for the National Environmental Monitoring and Prediction System. This agency should be given the responsibility for its funding and management.

C. Satellite Development and Operation

Research and development in satellite technology for oceanographic measurements should remain the responsibility of NASA. Funding and management of operational satellite systems for oceanographic monitoring should be a responsibility of the agency responsible for NEMPS. Such management arrangements have worked effectively for the National weather satellite program.

Recommendation:

The agency responsible for NEMPS should adopt arrangements with NASA for satellite oceanographic sensor development and operation similar to those which have worked effectively in the National weather satellite program.

VI. INTERNATIONAL ORGANIZATION

The international body responsible for coordinating real-time weather and surface ocean data collection is the World Meteorological Organization.

The Intergovernmental Oceanographic Commission has acted primarily as an international forum for research activities in oceanography, but has in the past year taken steps to plan and implement a global ocean-monitoring program (IGOSS). Although these activities are coordinated with the

WMO, questions arise regarding the respective domains of the IOC and WMO.

Weather and ocean monitoring and prediction programs are limited by insufficient data from the world's oceans. We have noted that the World Weather Program, under the aegis of the WMO, would provide additional sea-surface and ocean weather data. The President has endorsed this program for international cooperation in meteorological data collection, processing, and dissemination to improve weather forecasting, and the Congress has in its past session also endorsed the program in its concurrent resolution.

The close interaction between oceans and atmosphere would argue in favor of consolidating international operational activities in physical oceanography and meteorology in one international agency. If a major realignment of international agencies is contemplated, such an amalgamation should be among the alternatives considered; on the other hand, we recognize the close relationship between oceanographic data collection and other marine activities.

Recommendation:

Global oceanographic monitoring and prediction activities should be jointly planned with the World Weather Program to provide a well-coordinated and non-duplicating global ocean-atmosphere monitoring and prediction system.

VII. SYSTEMS STUDIES

Many of the technical devices which hold promise for an improved environmental monitoring and prediction service will be costly when fully deployed. Present cost-benefit/systems studies are not adequate for rational decision-making in regard to these major investments. Improved global prediction of oceanographic and atmospheric parameters depends on the interpretation of new types of observational data. Studies are required to determine the proper balance and mix of new data-collection platforms—satellites and buoys—with newly developed sensors. We must develop techniques to estimate changes in forecast capability as these potential new components are added to the existing system.

Recommendation:

Extensive analyses of design trade-offs, intended use of resulting data in prediction, and benefits from improved predictions must proceed in parallel with major technical development programs. Such analyses are required to support decisions regarding operational deployment of major new systems.

During the past fifteen years there has been a growing National awareness of man's dependence on the oceans and of the need for understanding the oceans and the life they sustain. A major indicator of this changing awareness is a series of reports on the marine sciences, reviewing the state of knowledge of the oceans and proposing future directions for oceanographic research. Two reports were submitted by the Committee on Oceanography of the National Academy of Sciences[1] (other pertinent reports of the National Academy of Sciences are referred to later in this report); another was submitted by the Panel on Oceanography of the President's Science Advisory Committee.[2] These reports stimulated the scientific community as well as legislators and administrators with the responsibility for the formulation of major National programs.

There are many reasons for our present concern with the marine sciences. We have long recognized that the oceans are primary avenues of international trade, that the oceans are a vital theater of National defense, that ocean storms destroy life and property, and that the oceans are a major source of food.

More recently, our awareness of the importance of the oceans has intensified. With the growing world's population increasing the pressure on food supplies, the natural resources of the oceans become vital. The expansion of industry and increased population density near the coasts have increased usage of harbors, estuaries, and near-shore waters with attendant pollution and conflicting pressures.

There is, in addition, the long standing recognition of the significant role that the oceans play in molding our weather.

Because man is dependent on the oceans, he has sought an understanding of the laws that govern their contents, motions, and dynamic processes, but he has done so under a severe handicap. On the one hand, it has been impossible to experiment with the ocean as a laboratory scientist would, conducting experiments in a limited space. On the other hand, the vastness of the oceans made it impossible to mount a continuous watch over them. Ships plying the major ocean trade routes cover only a small portion of the world oceans. It is not surprising, therefore, that present scientific knowledge of the oceans, while in some aspects impressive, is fragmentary.

But new technology has opened new possibilities. The earth-orbiting satellite, the ocean buoy, and associated technology provide a potential capability to observe and probe the oceans over the entire globe–to gather the data needed to describe, understand, and predict ocean processes. With modern communications techniques and high-speed computers, data can be transmitted rapidly over global distances to central locations to be processed, analyzed, and disseminated.

In this report, the Panel on Environmental Monitoring has concerned itself with how this new technology may be used to improve understanding of the oceans and the ability to predict their future state. We have reviewed present programs and plans and future possibilities for monitoring the ocean and the neighboring atmosphere and predicting their future states. Our primary concern has been with those programs for which observation are processed and analyzed within a relatively short time to provide useful predictions, i.e. essentially real-time activities.

The panel has concluded that the United States must accelerate its development–in concert with other nations–of a comprehensive global system for the monitoring and prediction of the physical environment. In the following chapters the panel will discuss the needs for such a global system, appraise present program performance, describe recent technical developments, discuss National and international management and coordination arrangements, and make recommendations for the future.

[1]Committee on Oceanography, National Academy of Sciences-National Research Council, *Oceanography 1960 to 1970*, NAS-NRC, Washington, D.C. (1959) (out of print); Committee on Oceanography, National Academy of Sciences-National Research Council, *Oceanography 1966, Achievements and Opportunities*, NAS-NRC, Washington, D.C. (1967).

[2]Panel on Oceanography, President's Science Advisory Committee, *Effective Use of the Sea*, Washington, D.C. (1966).

I. THE NEED FOR OCEAN KNOWLEDGE

The Nation has a pervasive need for detailed knowledge of the ocean's characteristics and an understanding of their changes in time and space.

One of the nation's primary concerns in oceanography is National security. Those who deploy, route, and operate naval vessels must have detailed data describing the state of the ocean's surface and the currents at different depths. They must have forecasts of the temperature, salinity, and biological composition of the oceans to ensure effective use of sonar. Detailed analysis of the thermal structure is necessary for the interpretation of passive sonar tracking data. The Navy requires forecasts of icebergs and sea-ice for operations in polar and sub-polar waters. For amphibious landings, naval forces require forecasts of tide, tidal currents, and surf conditions.

Another major concern is the protection of life and property. A hurricane can generate waves more than 50 feet high that batter whatever lies in their paths. The storm surge driven by hurricane winds erodes beaches, highways, and topples buildings. Since much of the U.S. densely populated Atlantic and Gulf coasts lies less than 10 feet above mean sea level, the danger is great. Hurricane Beulah, in September 1967, left at least 41 people dead, thousands homeless, and more than $1 billion in damage; the storm surge and floods caused most of the damage.[1] In recent years, mass evacuations have been ordered to save lives along the Gulf coast.

Tidal waves, or tsunamis, are not generated by winds but by earthquakes. Tsunamis occur most often in the Pacific and are a series of long ocean waves. In deep water these waves are difficult to detect and cannot be seen. They contain tremendous energy, and can devastate coastal areas, with waves of 100 feet or more. The Prince William Sound, Alaska, earthquake of 1964 cost approximately 150 lives; almost all the deaths were along the Alaska Gulf coast and the U.S. west coast caused by the resulting sea wave.[2]

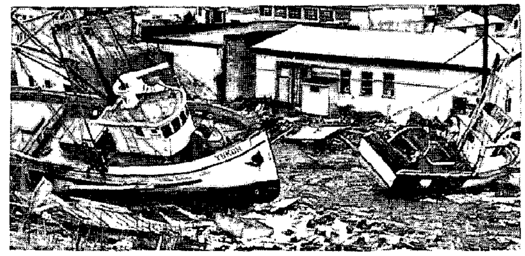

Figure 2. *General view of Kodiak, Alaska, showing damage caused by sea-wave resulting from earthquake, March 28, 1964. (ESSA photo)*

These are the most destructive ocean phenomena. But other storms, and the rough seas associated with them, are also dangerous and these storms can change quickly in intensity. They are a menace to all those operating offshore rigs for the extraction of oil and gas. The threat can be reduced by reliable forecasting of ocean conditions.

In addition to these requirements there are many anticipated future needs for specialized ocean predictions. As sea-bottom habitation and the use of deep-ocean submersibles become realities, deep-ocean forecasts will be required. New transportation developments—surface-effects machines and hydrofoils—will be particularly sensitive to sea-surface "roughness" and will require special sea-state forecasts.

Ocean knowledge can also serve the National economy in many ways. If the state of the oceans, particularly ocean waves and currents, can be predicted, ocean vessels can be routed more efficiently. An example of the vulnerability of major ships to the vagaries of the oceans is the recent loss of the 30,000 ton tanker *World Glory* off Durban, South Africa, with 22 hands.[3] A 70-foot high wave, called a "Cape-roller," snapped

[1] *Hurricane Beulah, Preliminary Report with Advisories and Bulletins Issued by the Weather Bureau,* U.S. Weather Bureau, ESSA, Sept. 29, 1967.

[2] *A Proposed NATIONWIDE NATURAL DISASTER WARNING SYSTEM (NADWARN),* Report with background information prepared by the Natural Disaster Warning Survey Group, ESSA, Department of Commerce, October 1965.

[3] Daily Bulletin of the American Institute of Marine Underwriters, 99 John Street, New York City, June 17, 1968.

off the ship's stern. Better understanding of surface waves would permit improvements in ship design to make ships cheaper to build and more efficient to operate. Forecasts of sea-ice are important for naval operations and commerce.

This knowledge is also vital for the operation of fishing vessels. The loss of three British trawlers off Iceland in February 1968, points up the ever-present danger. Ocean knowledge has an additional importance for the fishing industry. Ocean currents, temperatures, and other physical and chemical conditions strongly affect fisheries. The fluctuations in yield of the major ocean fisheries over periods of time are often a reflection of changes in ocean conditions. Certain species of tuna are closely associated with a fixed temperature range in the ocean. Prediction of the location of the appropriate isotherms increases the efficiency of this fishery operation.

These requirements—of those engaged in naval operations, in ensuring the safety of coastal areas, in operating small boats as well as ocean-going vessels, and in fishing—are operational requirements. But even if we could now observe the oceans everywhere, we could not satisfy all of these needs because the ability to forecast ocean conditions is limited by incomplete scientific understanding of the motions of the oceans—of their scale, their kinetic energy, and the causes of their fluctuations. In the last analysis, we must observe the oceans to collect the data that will permit the scientist to describe the initial state of the oceans and to establish the laws that govern their dynamic processes.

The oceans are massive and sluggish and their motions are in large part a response over a long period of time to motions in the atmosphere. In turn, the heat stored up by the oceans helps drive the atmosphere. Increased understanding of the oceans is therefore important not only for the improvement of ocean forecasting but also for the improvement of weather forecasting. Improved understanding is especially needed in the zone where sea and air meet. If the scientist can improve his understanding of the interactions between the atmosphere and the oceans we shall go a long way in improving our ability to predict the weather.

II. THE NEED FOR A COMMON GLOBAL SYSTEM

These are some of the Nation's more important needs for ocean knowledge. These needs can only be satisfied if we are able to maintain a continuous watch over the oceans and improve our capability to forecast. But how should we do this? Should each activity—the Department of Defense, the Department of Commerce, the Department of Interior, the shipping industry, the fishing industry—maintain the ocean watch it needs and be responsible for the forecasts it needs? Or should we have a separate system for each geographical area of the marine environment? These are some of the questions addressed by the Panel on Environmental Monitoring in this report.

There must be a single system providing data and forecasts to meet the common needs, for what emerges clearly from the description of the Nation's extensive needs for ocean knowledge is that different activities share many needs in common. These activities should be served by a system which meets the common needs in an efficient way. Separate observing and forecasting systems for each major activity would result in needless duplication. However, special classes of ocean "users" require specialized forecasts and/or data, which would be developed from outputs of the system designed to meet most common needs. The military will still require specialized outputs in support of military operations, fully responsive to rapidly-changing military requirements, provided by a system under control of the Defense Department. The system would provide data and predictions describing large-scale characteristics of the environment. In many cases, such as pollution control and marine resource management, smaller scale data are required; these would continue to be collected by local agencies and used in conjunction with larger-scale information.

A marine environmental monitoring and prediction system, if it is to provide all required data and services, must be global. There are two reasons for this conclusion:

—The Nation is engaged in marine operations, or must be prepared to engage in them, throughout the world—over all the oceans, and along every coast. This is particularly true for the Navy, but commercial vessels also traverse much of the globe and fishing vessels range widely.

–Equally important is the fact that the oceans are in constant motion over the globe. What happens in one area of the oceans can affect the oceans or coastal waters a thousand miles away. The marine environment cannot be viewed as a series of parts; only a global system can monitor the oceans and forecast its changes.

III. THE OCEAN-EARTH-ATMOSPHERE PHYSICAL SYSTEM

The report has thus far considered a monitoring and prediction system for the marine environment –but this is artifical because the oceans, the atmosphere, and the solid earth are not separate and distinct but are elements of the continuum which we call the geophysical environment. These elements are in constant interaction. To understand and predict the oceans, we must understand the total environment.

Similar conclusions were reached by the Committee on Oceanography of the National Academy of Sciences[4] and the Panel on Oceanography of the President's Science Advisory Committee.[5] We have reviewed this aspect of their reports with particular care, for it is crucial in determining the kind of monitoring and prediction system the Nation should develop. This panel concurs in the view that ocean conditions and processes cannot be monitored, studied, understood, and predicted in isolation, but only in the context of the total geophysical environment.

The validity of this view can be seen in different ocean phenomena. Ocean surface currents and the "shape" of the ocean surface, for example, are primarily the result of the winds in the lower atmosphere. Large ocean swells observed on the U.S. Pacific Coast are generated by winds in the atmosphere over the Southern Atlantic Ocean. The tsunami is a destructive ocean phenomenon, but it is generated by motions of the solid earth's crust. In their turn, the oceans affect what happens in all parts of the physical environment. The hurricane obtains its energy by absorbing sensible heat directly from the ocean and through the release of latent heat by condensation of water vapor supplied by the ocean.

Figure 3. *Eye of Hurricane Betsy, photographed by Air Force reconnaissance aircraft at an altitude of 11 miles, 90 miles north of Grand Turk Island, British West Indies, Sept. 2, 1965. (Air Force photo)*

On a longer time scale the oceans play a large role in the general circulation of the atmosphere, although geophysicists feel that the earth's north-south energy balance is primarily maintained by atmospheric circulations.[6] At high latitudes, for example, cold ocean water sinks in certain regions and flows toward the equator at great depths. Even a weak circulation of this type results in a relatively large transport of energy toward the poles. At present the magnitude of this oceanic energy flux and its role in maintaining the earth's energy balance is unknown.

At least as important is the fact that the air-sea water exchange is the mechanism that provides the water for precipitation over the globe. So pervading is the total atmosphere-ocean exchange that it has been hypothesized that shifts in the positions of major ocean currents may be responsible for

[4]Committee on Oceanography, National Academy of Sciences-National Research Council, *Oceanography 1966–Achievements and Opportunities,* NAS-NRC, Washington, D.C. (1967).

[5]Panel on Oceanography, President's Science Advisory Committee, *Effective Use of the Sea,* Washington, D.C. (1966)

[6]Joint Panel on Air-Sea Interaction, National Academy of Sciences-National Research Council, *Interaction Between the Atmosphere and the Oceans,* NAS-NRC, Washington, D.C. (1962).

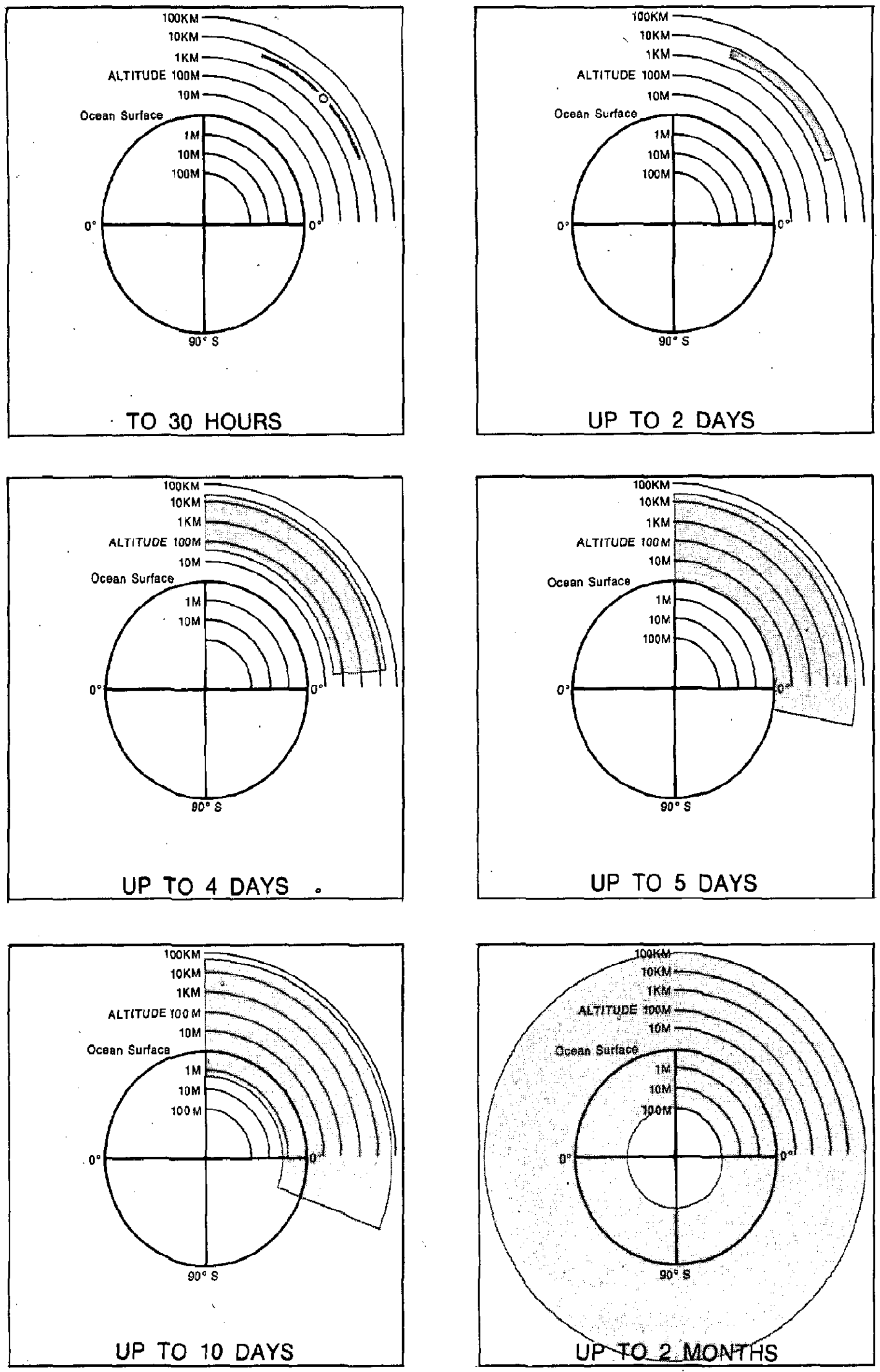

Figure 4. *Estimated initial data requirements to forecast for a point at the 500-millibar surface (about 6 kilometers) at latitude 45°N. For a forecast period of up to 30 hours, initial data are required from a strip at the same altitude over the Northern Hemisphere; 30 hours-2 days, a thin layer of atmosphere over part of the Northern Hemisphere; 2-4 days, a deep layer of atmosphere over most of Northern Hemisphere; 4-5 days, a deep layer of atmosphere over the entire Northern and part of the Southern Hemisphere plus sea-surface data; 5-10 days, same part of atmosphere as for 4-5 days plus the ocean to 4 meters; and 10 days-2 months, atmosphere over entire globe plus the ocean to 100 meters. (Adapted from Hallgren, R. E., "World Weather Program,"* TRW Space Log, *spring-summer 1968)*

long-term weather "shifts"[7] i.e. droughts, unseasonably warm summers, etc. Figure 4 is a schematic estimate of the dependence of atmospheric forecasting on oceanographic data; it shows how increasing amounts of ocean data are required as the time range of a forecast for the atmosphere is increased.

In regard to forecasting ocean conditions and their effects on fisheries, Schaefer has stated:[8]

We are, I believe, on the threshold of being able to do much better, through monitoring of atmospheric circulation and heat exchange between sea and atmosphere.... These are the principal driving forces on the upper layers of the sea, and the dynamic relationships between them and the ocean circulation are becoming increasingly better understood. It should soon be possible, given an adequate network of stations for observations of the atmosphere over the sea and of the upper layer of the ocean, by automatic unmanned stations (meteorological and oceanographic buoys) both to keep track of what the ocean is doing, in real time, and to forecast changes which will affect the fisheries.

The relationship between the physical processes of the marine environment and of the atmosphere is so intimate that physical oceanography and meteorology are inextricably bound together. An understanding of the exchange of heat between sea and air—of the ways in which the winds drive the oceans—is integral to the scientific understanding of ocean or atmosphere; and it is integral to forecasting in the ocean and in the atmosphere. Any system for monitoring the oceans and predicting their changes must, therefore, be concerned with atmospheric data, just as any system for monitoring and predicting the weather must be concerned with ocean data. Logic demands a single monitoring and prediction system for the total physical environment.

IV. COMMON ELEMENTS IN ENVIRONMENTAL MONITORING AND PREDICTION

Not only are the oceans and the atmosphere linked by interacting processes, but the technologies for observing and communicating oceanographic and meteorological data have many features in common. Because of the high cost of acquiring data over the oceans it is necessary to share platforms for observing the ocean and the atmosphere. The Nation cannot afford separate satellite or buoy systems for the acquisition of ocean data and atmospheric data; it cannot afford separate communications systems for oceanographic and meteorological data. The marine environmental data acquisition systems and communications facilities must be organized to ensure economical operation.

The safety and efficiency of any enterprise, a naval force or a fishing fleet or a shore community, depends on the totality of environmental conditions confronted. The fisherman must know the weather and the state of the sea as well as the currents and temperature distribution within the ocean. The coastal homeowner is concerned not only with the atmospheric winds under severe storm conditions but also with the storm surge.

Our views are not abstract; today's marine environmental monitoring and prediction systems are "integrated." The Navy, operating the Nation's most advanced marine environmental monitoring and prediction service, conducts many of its weather and ocean forecasting activities jointly at the Fleet Numerical Weather Central, Monterey, California. (See Chapter 3.) Both meteorological and oceanographic data are fed into computers; mathematical models describing both atmosphere and ocean are used to prepare ocean and weather analyses and forecasts. The Navy distributes both oceanographic and meteorological "products" over a single world-wide communications system.

ESSA provides both weather and marine information on storm surges and sea state through a single forecasting and dissemination system. It also plans to use weather satellites to observe sea surface temperatures.

Internationally, most ocean data are collected at the same time that weather observations are taken. These observations of the ocean state are com-

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[7] Namias, Jerome, Short-Period Climatic Fluctuations, *Science*, Vol. 147, No. 3659, Feb. 12, 1965, pp. 696-706.

[8] Schaefer, Milner B., Oceanography and the Marine Fisheries, *Canadian Fisheries Reports*, No. 5, June 1965, p. 35.

municated world wide through weather communications facilities organized by the World Meteorological Organization. (See Chapter 8.)

V. ENVIRONMENTAL MODIFICATION

During the past decade we have become increasingly aware of the ways in which man is inadvertently modifying his environment—through the emission of carbon dioxide, the discharge of industrial and agricultural pollutants—and of the possible ways in which he may be able to modify his environment deliberately—by coating surfaces to hasten or retard the absorption of heat and by releasing chemicals into the atmosphere to alter the ways in which it stores or releases water vapor. Inadvertent modification may pose a serious threat. The carbon dioxide in the atmosphere is increasing as a result of the burning of fossil fuels; the effect of the carbon dioxide on the earth's heat radiation has caused concern, because of possible long-term climatic changes.[9] But the oceans affect this process by absorbing carbon dioxide; the rate at which this occurs is not well documented.

Deliberate environmental modification holds out the ultimate hope that we can learn how to dissipate hurricanes and other severe storms and that we can provide certain areas of the world with slight increases in rainfall or small changes in average temperature and so make possible a viable agricultural economy where none was possible before. But modification is a matter of the total environment. When, for example, we modify the atmosphere, particularly on a large scale, there can be serious oceanic effects; the converse is equally true.

An improved global environmental monitoring system will make possible the collection of data vital in evaluating modification experiments. Increased understanding of the environment will make it possible to estimate the effects of proposed modification activities.

Recommendation:

The Nation's oceanographic monitoring and prediction activities should be integrated with the existing National weather system (as well as certain aspects of the solid earth) to provide a single comprehensive system, which the panel has identified as the National Environmental Monitoring and Prediction System (NEMPS).

Provisions should be made for:

–Immediate improvements in the present system through the increased use of equipment which is already available and which can be deployed at modest cost.

–Development of new technology to improve data acquisition, communications, and processing on a global basis, with systems studies proceeding in parallel.

–Research to remove present scientific limitations on our ability to predict the state of the ocean, its biota, and the atmosphere.

–A single civil system to meet common needs for environmental observations and forecasts of all agencies and users.

–Specialized systems to meet needs of the Department of Defense and other agencies, planned and coordinated with the common system.

The panel proposes that the Nation establish as a target the full implementation of a modernized and expanded global environmental monitoring and prediction system by 1980.

–The first half of the next decade should be devoted to immediate improvements in the system which could be introduced at low cost with existing technology, and to the development of new technology which will be necessary to realize the full range of possibilities.

–By 1975 the Nation should be in position to relate the potential improvement due to deployment of new technology to associated costs.

–By 1980 the next-generation system should be in place to provide adequate data coverage and services to meet the National needs.

[9] Environmental Pollution Panel, President's Science Advisory Committee, *Restoring the Quality of Our Environment*, The White House, November 1965.

I. HISTORICAL DEVELOPMENT

The Nation has long recognized the need for marine prediction in support of the many requirements cited in earlier chapters. The first well-known chart of the Gulf Stream was published by Benjamin Franklin in 1783, while he was Postmaster General, to speed the delivery of transatlantic mail. As early as 1842, Lieutenant Maury of the U.S. Navy began compiling wind and current charts from reports included in the log books of sailing vessels. Maury recognized the need for more data to make his charts more representative. He wrote letters to scientists all over the world asking for support in establishing a universal system for collecting weather observations on sea and land.

After a period of inactive duty following an injury Maury was recalled to active duty on July 1, 1842 to become superintendent of the Navy's Depot of Charts and Instruments. The agency was then renamed National, or Naval Observatory when it moved into new quarters in 1844. (From 1854 to 1866 it was called "Naval Observatory and Hydrographical Office"; in 1866 the Hydrographic Office was separated from the Naval Observatory.)[1]

As a result of Maury's early actions, a meeting was held in Brussels in 1853 which included representatives of all the world's maritime nations. Maury tried to establish the concept of cooperation in making weather observations on land, but that goal was not achieved; instead, it was decided to limit cooperation to observations at sea. It is still possible, however, to trace the establishment of national meteorological offices in Great Britain and Germany to his influence. Later response to Maury's influence resulted in the establishment of hydrographic services in other maritime nations. In 1854, a storm at Balaklava on the Black Sea wrecked the French fleet; as a result the French high command demanded and got the first synoptic weather service. In 1867, tide prediction tables were published by the Coast Survey and in 1870 the National Weather Service was established as part of the U.S. Army Signal Service.

The first explicit Congressional recognition of the need for comprehensive marine intelligence to benefit commerce was in the 1890 legislation passed by the 51st Congress, which established the U.S. Weather Bureau under the direction of the Secretary of Agriculture (cf. Chapter 7). The Chief of the Weather Bureau was assigned responsibility for the "collection and transmission of marine intelligence" as well as weather forecasting. Since then, many agencies in the Federal Government have found the acquisition and use of marine intelligence essential to the conduct of their missions.

Marine environmental monitoring and prediction activities have grown in response to many needs which have developed over the years. The panel has sought to ascertain whether this growth, in response to pressing requirements, has produced a system that is as efficient as the Nation needs. On the basis of data gathered by the panel in its hearings, and in the review of present and planned Federal programs, we feel that certain programs can be improved and other changes should be made; these matters are covered by the recommendations contained in this chapter, as well as those of Chapter 7 regarding organization.

A number of Federal agencies conduct one or more of the following activities: acquisition of physical oceanographic and related meteorological data, the communication of such data, processing data, forecasting, disseminating analyses and forecasts. A number of relatively independent regional programs are also in operation to provide biological forecasts. The Departments of the Interior, Commerce, Defense, and Transportation are all involved in one or more aspects of the overall national marine environmental monitoring and prediction program. In the remainder of this chapter we describe the programs of these Federal agencies. We have not attempted to present detailed fiscal data for all activities described, but give general funding levels to indicate the magnitude of the effort.

[1] Maury, Mathew Fontaine (edited by John Leighly) *The Physical Geography of the Sea and its Meteorology*, The Belknap Press of Harvard University Press, Cambridge, Massachusetts, 1963, 427 pp. (p. xi).

II. MAGNITUDE OF FEDERAL EFFORT

A summary of overall funding for the operational marine environmental monitoring and prediction service is given below. Its funding can be considered in three categories:

–Funds expended for the collection, processing, and dissemination of ocean measurements not collected in connection with meteorological services.

–Funds expended for specialized marine weather data collection and processing which are to meet the exclusive need for support of marine activities.

–Funds expended for associated meteorological and oceanographic data collection and processing that are essential for ocean observation and forecasts, but which are also collected to meet more general, non-marine needs of the National civil and military weather services.

An estimate of the present annual cost to the Nation for providing marine weather and ocean environmental services may be obtained by adding the funds in these three categories:

a. Ocean Observing and Prediction Program	$ 21 million
b. Marine Weather Program	12 million
c. Associated Meteorological Program	140 million
Total	$173 million

The funding estimate for FY 1969 for each of the Federal agencies for ocean observation and prediction (category a.), and/or marine weather services (category b.), is shown in Table 1.

The National civil and military weather services are the principal sources of weather data and forecasts essential to support marine environmental services. The meteorological programs of the Department of Commerce, Department of Defense, and Department of Transportation provide the following data under category c:

–Surface and upper-air observations from coastal and island stations.

–Surface and upper-air observations from the cooperative merchant ship program, and other vessels.

Table 1
ESTIMATED FUNDING LEVEL FISCAL YEAR 1969 MARINE ENVIRONMENT MONITORING AND PREDICTION SERVICES[1]
(Thousands of Dollars)

	Ocean (Category a)	Marine Meteorology (Category b)
Commerce	$ 4,868	$ 977
Defense-Navy	9,267	10,311
Interior-BCF	175	0
Transportation-Coast Guard	6,800	262
Totals	$21,110	$11,550

Source: Category a: National Council on Marine Resources and Engineering Development, Committee on Ocean Exploration and Environmental Services, *Federal Plan for Marine Environmental Prediction*, Washington, D.C., July 1, 1968; Category b: Office of the Federal Coordinator for Meteorological Services and Supporting Research, *The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1969*, Washington, D.C. (1968)

[1] Data subject to revision as spending plans become firm.

–Surface observations from cooperative coastal stations.

–Surface and upper-air observations from the Ocean Station Vessels.

–Weather radar observation of thunderstorms and precipitation over the United States, and of tropical cyclones and storms in offshore areas.

–Weather satellite observations of the earth's cloud patterns.

–Aircraft observations of tropical cyclones and major storms over the oceans.

Table 2 is a summary of estimated Fiscal Year 1969 funding levels for the operational programs described above, which are essential to the support of monitoring and prediction services.

Table 2.
ESTIMATED FUNDING LEVEL – FISCAL YEAR 1969
OPERATIONS TO PROVIDE DATA NEEDED TO SUPPORT THE NATIONAL MARINE ENVIRONMENTAL SERVICES PROGRAM[1]
(Thousands of Dollars)
(Category c.)

Commerce	93,175
Defense	
Air Force	21,500
Navy	8,150
Transportation	
Coast Guard	6,760
FAA	7,890
TOTAL	137,475

Source: Office of the Federal Coordinator for Meteorological Services and Supporting Research, *The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1969*, Washington, D.C. (1968)

[1] Data subject to revision as spending plans become firm.

III. PROGRAMS OF FEDERAL AGENCIES[2]

A. Department of Defense

The Air Force conducts extensive environmental observing and prediction programs, primarily the collection of atmospheric data at certain locations in the United States and overseas. The Air Force also operates regular weather reconnaissance flights over ocean areas. However, the bulk of the Defense Department activities of concern to the panel is conducted by the Navy.

All commissioned naval vessels are required to record and report weather observations when underway and, under certain conditions, while in port. Six-hourly surface observations are made by non-meteorological personnel. For more accurate and detailed observations and duties, meteorological personnel are assigned to approximately 75 ships. All these ships make scheduled surface observations for synoptic and aviation purposes; approximately 55 are equipped to make upper-air observations. The Navy also obtains some data from Navy Oceanographic/Meteorological Automatic Devices (NOMADs), now undergoing operational evaluation (see Chapter 5). The Navy's marine observational program is conducted to fulfill military requirements, but observations are also made available to the Department of Commerce. The Navy's operational program is primarily the responsibility of the Naval Weather Service Command.

[2]The descriptions of Federal agency programs have been reviewed by the cognizant agencies.

1. Naval Weather Service Command

The missions of the Naval Weather Service Command are:[3]

1. Provide meteorological services for air, surface, and sub-surface operations of the U.S. Navy.
2. Provide oceanographic forecasts for the armed services of the Department of Defense in order to support military plans and operations.

In addition to the more familiar maritime forecasts–fog, small craft, gale and storm warnings, high seas warnings–the Naval Weather Service Command provides operational oceanographic support to the fleet. Forecasts cover sea state, surf and littoral currents for amphibious operations, physical oceanographic parameters for anti-submarine warfare, wind-driven currents for search and rescue missions, sea ice conditions for polar missions, and Optimum Track Ship Routing (OTSR), an advisory service for ship track selection to avoid hazardous wind and sea conditions.

Fleet Weather Centrals at Alameda, California; Norfolk, Virginia; Pearl Harbor, Hawaii; Guam; and Rota, Spain, operate as area centers. They use the broad-scale products from the Fleet Numerical Weather Central (see next section) and from ESSA's National Meteorological Center to prepare detailed analyses, forecasts, and warnings for their areas of responsibility (See Figure 5.) Fleet Weather Central products are disseminated to naval operating forces and to smaller naval environmental units by the Naval Communications System.

[3]Office of the Chief of Naval Operation, OPNAV Instruction P3140.32A.

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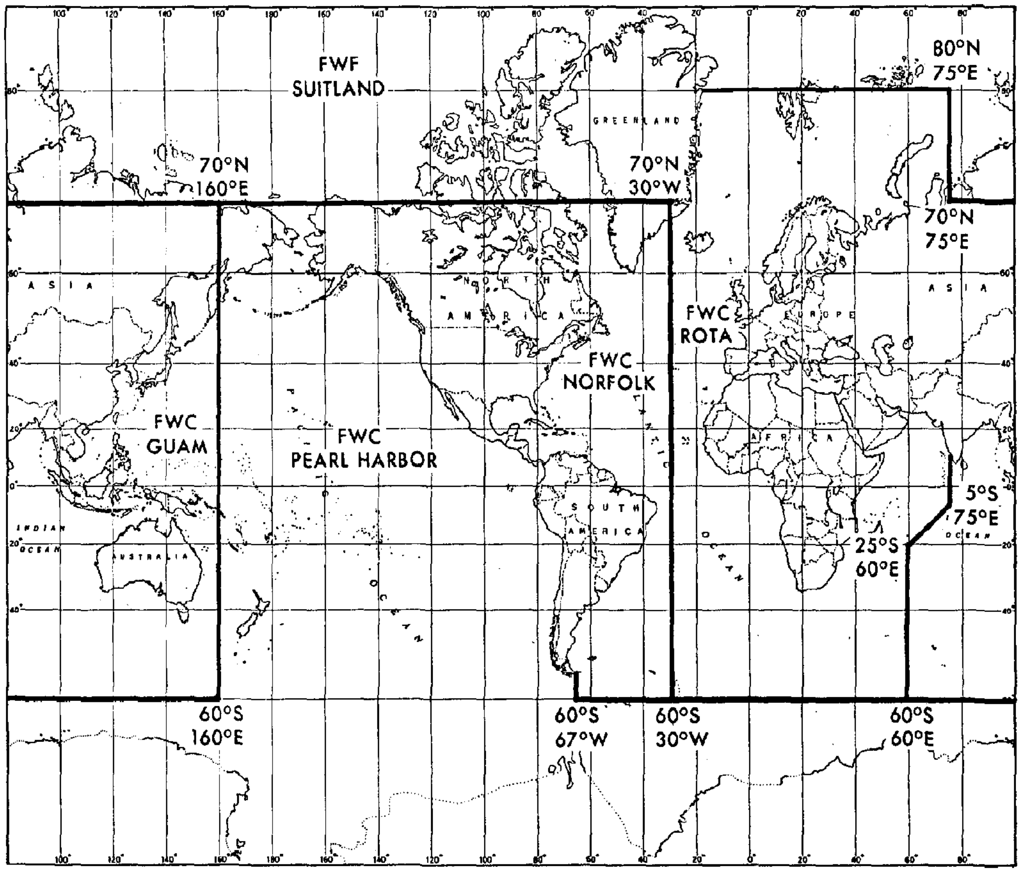

Figure 5. *Naval Weather Service Command areas of responsibility.*

The Navy Fleet Weather Centrals and Facilities have operational oceanographic divisions, manned by personnel trained in both meteorology and oceanography. Fleet Weather Centrals and Facilities, acting as regional operational oceanographic support centers, provide technical guidance to Naval Weather Service Environmental Detachments (NWSED's) and mobile oceanographic teams aboard ships in order to help tailor their services to the user's needs.

The Navy operates Fleet Weather Facilities at Yokosuka, Japan; Sangley Point, Phillippine Islands; San Diego, California; Jacksonville, Florida; Quonset Point, Rhode Island; Kodiak, Alaska; Argentia, Newfoundland; Keflavik, Iceland; and London, England as specialized centers. These Facilities provide forecasts and warnings tailored to specific naval operating and training areas. Many Fleet Weather Facilities and Weather Centrals have other specific responsibilities: Argentia and Kodiak provide ice forecasting services; Alameda and Norfolk operate the Navy's Optimum Track Ship Routing Program (this program provided routing services for 3980 DOD ships in 1967). Guam is the site of a joint Navy/Air Force typhoon warning center. All activities of the Integrated Fleet Weather Central System participate in the Anti-Submarine Warfare Environmental Prediction System (ASWEPS).

The Fleet Numerical Weather Central (FNWC), Monterey, California is the center of the weather and oceanographic data-processing computer network; it is also the center for computer program development for the Naval Weather Service Command. FNWC issues operational analyses/forecasts covering thermal structure, sound-speed structure, wave conditions, and surface currents in support of fleet operations.

The most significant FNWC forecasting activities are the thermal structure programs for the

Northern Hemisphere, including analyses and forecasts of sea-surface temperature, and near-surface temperature structure. Upon request FNWC will also provide bathythermograph (temperature vs. depth) profiles from thermal structure analyses/forecasts for any location in the Northern Hemisphere, as required, and classified sonar analyses/predictions for fleet operating areas.

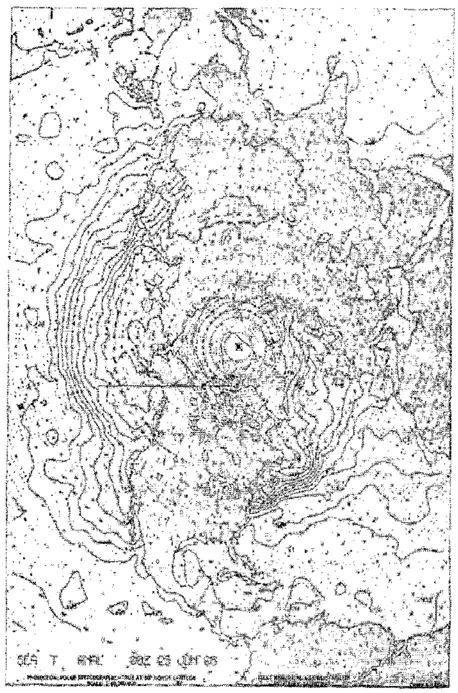

Figure 6. *Portion of sea surface temperature analysis prepared by computer installation at Navy's Fleet Numerical Weather Central, Monterey, California. Chart is for 0000 GMT, June 25, 1968; contour lines are marked in degrees centigrade.*

Wave forecasting programs for the Northern Hemisphere conducted by the FNWC include twice-daily sea and swell analyses and 12-hour forecasts of height, period, and direction for sea and swell.

Surface current programs conducted by the FNWC include daily forecasts and twice-daily analyses of surface currents, together with twice-daily computations of the locations of major current boundaries.

2. Navy Communications

The Naval Communications System transmits meteorological information in the same manner as other communications traffic. A Naval Environmental Data Network has been established for the exchange of meteorological and oceanographic computer products between the FNWC and the Integrated Fleet Weather Central System activities. This network is composed of high speed digital circuits, which also serve certain Naval Operations Control Centers, and selected ASWEPS units.

Meteorological information, prepared by the Fleet Weather Centrals and Facilities, is transmitted to operating Naval forces by means of Navy radio (continuous wave, teletypewriter, facsimile, and voice) broadcasts. The centrals and facilities use their own specialized products, and those of the FNWC as well as products of the Basic Meteorological Service and other data from the Federal Aviation Administration's weather teletypewriter networks, the Department of Commerce's National and High Altitude Facsimile Networks, and the Air Force's Automated Weather Network and teletypewriter systems.

The primary purpose of the Navy's Integrated Fleet Weather Central System is to support operational decisions. Weather service offices at all major naval commands and aboard many larger ships use the products of the Integrated Fleet Weather Central System. They interpret these products for local use and prepare local area and route forecasts.

3. Naval Oceanographic Office (NOO)

The Naval Oceanographic Office is responsible for developing oceanographic prediction techniques and applying them to Naval operations on an experimental basis. As methods reach operational utility, they are transferred to the Commander, Naval Weather Service Command, although NOO also conducts some operational activities.

NOO's ASWEPS program has both operational and research and development facets. A prototype system is in operation in the western North Atlantic Ocean which provides both daily and long-term forecasts of sea-surface temperature, thermal layer depth, and in-layer thermal gradients.[4] A dynamic prediction model is being tested to replace the analysis techniques used in the prototype system.

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[4] Forecasting procedures are described in: James, R. W., *Ocean Thermal Structure Forecasting.*

The ASWEPS development program is continuing toward the establishment of an operational MARK II Anti-Submarine Warfare Environmental Prediction System which will give worldwide coverage. ASWEPS is also the focal point for the development of pertinent environmental instrumentation for naval ship and aircraft use. NOO produces operational wave forecasts by non-numerical methods[5] and is evaluating numerical techniques. NOO's operational ice prediction programs include general forecasts in the Arctic and Antarctic and forecasts in support of under-ice cruises. Long-range (greater than 30 to 120 days) and 30-day forecasts are provided during March through November for eastern North American Arctic seas, including east Greenland waters; Baffin Bay; the Labrador, Bering, and Chuckchi Seas; and limited areas of the Canadian Archipelago. Long-range and 30-day forecasts are provided for Antarctic waters, including the Ross Sea and McMurdo Sound, during October through January. Operational sea-ice forecasts are also provided for under-ice submarine cruises along tracks to and beneath the Arctic Ocean.[6]

NOO developed the optimum ship routing program based on sea and swell forecasts. This program has been passed on to the Naval Weather Service Command for operational use. However, NOO still routes a limited number of ships in order to evaluate new techniques.

4. Army Corps of Engineers

The Lake Survey of the Army Corps of Engineers monitors the flow in and out of the Great Lakes. The Army Corps of Engineers is active in the study of beach erosion processes. As part of its program, ocean waves are monitored at several locations on the east, west, and Gulf coasts. The east coast stations are operated as part of a test system; data is transmitted continuously to a central location in Washington and recorded on magnetic tape. The Corps also monitors beach erosion and shoaling in channels; these processes are studied and predictions made in connection with planned engineering developments.

B. Department of Commerce

1. Environmental Science Services Administration (ESSA)

The mission of the Environmental Science Services Administration is:[7]

.01 To ensure the safety and welfare of the public, to further the Nation's agriculture, industry, transportation, and communications, and to assist those Federal departments and agencies that are concerned with the national defense, the exploration of outer space, the management of the Nation's mineral and water resources, the protection of the public health against environmental pollution, and the preservation of the Nation's wilderness and recreation areas, the Administration shall perform the following functions:

a. Observe and collect comprehensive data about the state of the oceans and inland waters, of the upper and lower atmosphere, of the space environment, and of the earth;
b. Communicate, correlate, process, and analyze all such environmental data;
c. Provide and disseminate information about the state of the oceans and inland waters, of the upper and lower atmosphere, of the space environment, and of the earth, and predictions of their future states;
d. Prepare and disseminate warnings of all severe hazards of nature to all who may be affected;
e. Provide nautical, aeronautical and telecommunication charts and related publications and services;
f. Operate and maintain a system for the storage, retrieval and dissemination of data relating to the state of the oceans and inland waters, of the lower and upper atmosphere, of the space environment, and of the earth;
g. Explore the feasibility of modification and control of environmental phenomena;
h. Coordinate Federal meteorological services and supporting research;

[5] These techniques are described in Pierson, W.J., G. Neumann, and R. W. James, *Practical Methods for Observing and Forecasting Ocean Waves by Means of Wave Spectra and Statistics.*

[6] Short-term ice forecasting methods presently in use are described by Wittmann, W. I., and G. P. MacDowell, *Manual of Short-Term Sea Ice Forecasting.*

[7] Department of Commerce Order 2A.

i. Acquire, analyze and disseminate data and perform basic and applied research on the propagation of electromagnetic waves;

j. Perform research and development relating to the oceans and inland waters, the lower and upper atmosphere, the space environment, the earth, and the use of the electromagnetic spectrum for telecommunications purposes, as may be necessary or desirable to develop an understanding of the processes and phenomena involved, and research and development relating to the observation, communication, processing correlation, analysis, dissemination, storage, retrieval, and use of environmental data as may be necessary or desirable to permit the Administration to discharge its responsibilities.

ESSA operates three primary centers which support its marine weather activities. The National Meteorological Center (NMC) at Suitland, Maryland, provides broadscale meteorological analyses and prognoses on a hemispheric basis. The National Environmental Satellite Center, also at Suitland, operates the National Operational Meteorological Satellite (NOMS) System to provide global cloud cover mosaics, sea-ice information, and other interpretive data on a daily basis. The National Hurricane Center at Miami, Florida, provides hurricane forecasts and warnings in the North Atlantic Ocean (west of 35°W), the Caribbean Sea, and the Gulf of Mexico.

Fourteen area forecast centers are operated within the 50 States and Puerto Rico to provide marine weather analyses, forecasts, and warnings for their areas of responsibility. The centers at Boston, Washington, Miami, New Orleans, and San Juan provide limited forecast and warning service for fishing fleets operating in the North Atlantic Ocean (west of 60°W), the Caribbean Sea, and the Gulf of Mexico. Forecasts and warnings for the Great Lakes are issued by the Chicago center.

The Coastal Warning Display system is a cooperative network of visual (flag and light) displays maintained at prominent locations along the seacoasts, the Great Lakes, and inland waterways to advise boating and other marine interests when small craft, gale, storm and hurricane warnings are in effect.

ESSA publishes, on an annual basis, predictions of tides and tidal currents. It also issues operational forecasts of tsunami arrival times, storm surges, and sea-swell-surf conditions.

ESSA predicts the times and heights of high and low waters for 54 stations in the U.S. and its possessions. These predictions are also available for 39 stations in 18 different nations and U.N. Trust Territories. Tide predictions are published each year (approximately six months in advance). The Coast and Geodetic Survey (preceding the formation of ESSA) has been publishing tide predictions since 1867.

ESSA also predicts the times of slack waters and the times, speeds, and directions of maximum tidal currents for 35 coastal and harbor stations in the United States. Charts showing the distribution of tidal currents are available for nine major U.S. harbors and estuaries. Tidal current predictions have been published since 1890. ESSA carries out a comprehensive tide and tidal current data collection program; all tide and tidal current predictions of the U.S. Government are based on these data.

The Tsunami Warning System, in operation since 1948, provides predictions of arrival times of potentially dangerous tsunamis. These predictions are sent (for subsequent dissemination) to 10 nations bordering the Pacific Ocean and to the States of California, Oregon, Washington, Hawaii, and Alaska (including the Aleutian Islands). In addition, U.S. possessions, U.N. Trust Territories under U.S. supervision, and U.S. military activities receive these tsunami warnings.

A storm surge warning service for U.S. coastal areas on the Atlantic Ocean and Gulf of Mexico is operated by ESSA, in conjunction with the hurricane warning service. In support of the storm surge warning service, ESSA is developing storm surge models as well as techniques for forecasting extra-tropical storm surges. Seiche and storm surge forecasts for Lake Michigan and Lake Erie are issued routinely.

Surf and breaker forecasts for the Los Angeles-San Diego coastal area are provided by the Los Angeles area center in cooperation with the Navy's FNWC. A wind-wave and swell forecasting program, based on techniques developed by the Navy, is undergoing operational evaluation; the program uses meteorological forecasts produced by ESSA's NMC.

Three area centers also provide analysis and forecast services to meet U.S. responsibilities to the World Meteorological Organization. The center at Washington issues high seas forecasts and warnings for the North Atlantic (west of 35° W). Similar services are provided by the centers at San Francisco and Honolulu for the eastern and central North Pacific Ocean. High seas service responsibilities in the western North Pacific Ocean (between 135°E and 160°E) are met by the Department of Defense (see Figure 7).

The Northern Hemisphere data collection program which supports this meteorological forecasting and warning system acquires some oceanographic data, such as sea surface temperature and wave heights, on a routine basis. The National Meteorological Center is developing numerical models for predicting monthly-mean ocean temperatures in support of research on extended and long-range weather forecasting.

ESSA's National Weather Records Center at Asheville, North Carolina, is responsible for processing and archiving meteorological records and some oceanographic data including sea state, and sea surface temperatures recorded by naval and merchant vessels. Summaries are included in various Commerce, Coast Guard, Navy, and WMO publications. In addition, data cards are exchanged with other major maritime nations. The Navy provides financial support. Specialized processing of weather observations from naval units, and the preparation of marine climatological studies are performed by NWRC under reimbursable funding arrangements.

2. ESSA–Communications

The provision of marine weather services depends on the following meteorological communications systems, which also serve many other functions:

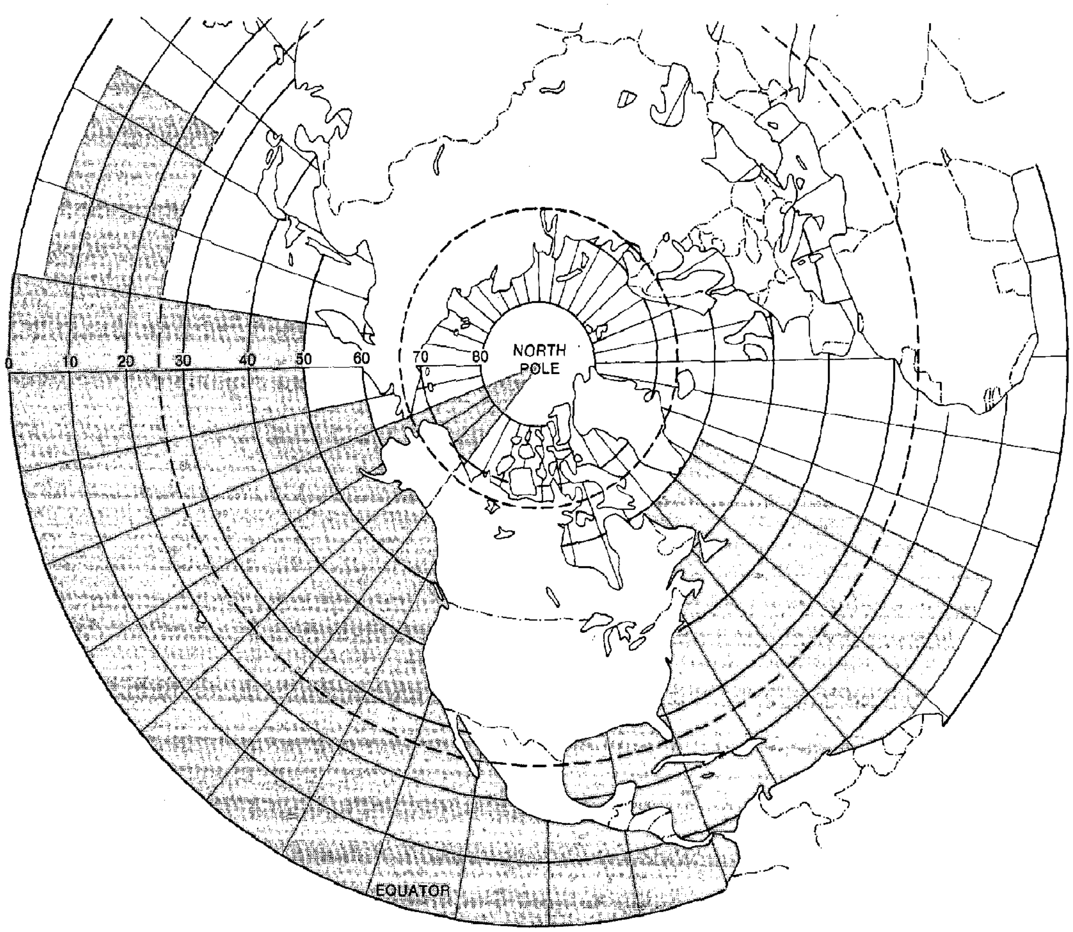

Figure 7. *Areas of U.S. shipping forecast and warning responsibilities under the World Meteorological Organization.*

–Certain Teletypewriter Systems operated by the Federal Aviation Administration.

–Radar Reporting and Warning Coordination System, a teletypewriter system operated by the Department of Commerce.

–Teletypewriter and high speed circuits operated by the Department of Commerce for collecting and exchanging overseas information.

–ESSA Weather Wire, a teletypewriter system to distribute forecasts and warnings to the press, radio, and television.

–Facsimile networks.

–Continuous VHF/FM radio broadcasts[8] operated by the Department of Commerce.

The Department of Commerce operates automatic telephone answering systems and has arranged for radio broadcasts to marine users over Coast Guard, Navy, Army, and commercial radio facilities. An automatic telephone answering system operates throughout the year at Baltimore, Washington, Juneau, Seattle, Chicago, and Los Angeles; service is also provided at Boston and Providence during the boating season. These systems provide the latest forecasts and warnings for marine users in their areas.

More than 2,000 commercial radio and television stations broadcast marine weather forecasts and warnings several times daily as a public service. Forecasts and warnings for coastal and offshore areas are also transmitted by 31 Coast Guard, 10 Army (in Alaska), and 39 commercial radiotelephone and radiotelegraph installations. High seas analyses, forecasts, and warnings are provided to merchant ships operating in the western North Atlantic and eastern and central North Pacific Oceans by Navy and commercial radiotelegraph broadcasts. Warnings for the western North Atlantic and eastern North Pacific are also transmitted by commercial radiotelegraph stations.

[8]Communications support is provided at no cost to the Department of Commerce by the Coast Guard, Navy, and many commercial facilities.

C. Department of Transportation

1. Federal Aviation Administration

The Federal Aviation Administration collects meteorological data at many airports in the U.S., and provides basic communications systems for the transmission of weather data.

2. Coast Guard

The Coast Guard operates two weather offices in support of Search and Rescue (SAR) operations. These offices, located at the Rescue Coordination Centers in New York and San Francisco, provide advice to commanders directing rescue operations and transmit specialized forecasts to ships and aircraft which are engaged in SAR operations. These Centers can receive oceanographic forecasts from the Navy's FNWC and disseminate these forecasts as needed.

The Coast Guard provides operational forecasts of iceberg movement and ice-season severity. Ice data from aerial reconnaissance are combined with meteorological information to forecast ice-season severity prior to the iceberg season. The Coast Guard also conducts an annual aerial census of icebergs in the Labrador Sea and Baffin Bay during September and January. During the iceberg season the Coast Guard maintains an oceanographic

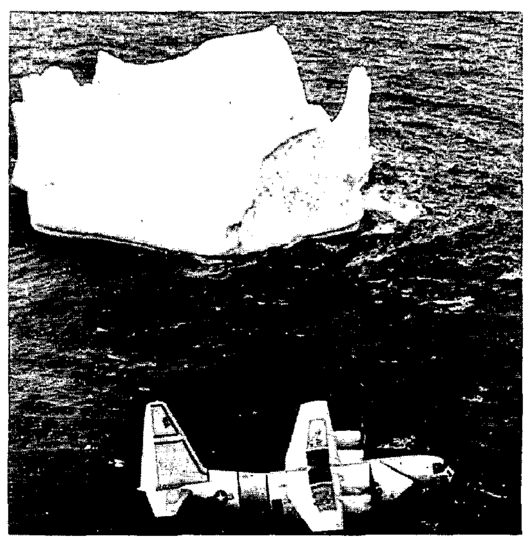

Figure 8. *U.S. Coast Guard* Hercules *ice patrol plane from Argentia, Newfoundland, tracking an iceberg along the Grand Banks. The plane is also equipped with a microwave radiometer for ice observation through clouds. (Coast Guard photo)*

ship adjacent to the North Atlantic traffic lanes; this ship maps oceanographic data, including currents. These data are correlated with sea-surface temperature data and meteorological data to forecast iceberg drift and deterioration. Satellite photographs, airborne infrared and radiometric observations assist in forecasting, as well as in empirical studies of sea ice. Ice information is broadcast twice daily by the Coast Guard radio station, Argentia, Newfoundland. Special forecasts and ice routing instructions for shipping interests are made available on request.

The Coast Guard provides input data to other agencies' forecasting programs, including synoptic oceanographic data from ocean stations and offshore light stations. The Coast Guard also supports observation programs of various governmental agencies, including:

–Tide level, water level, and wave observations for ESSA and the ~~U.S.~~ Lake Survey and Coastal Engineering Research Center (CERC) of the Army.

–Visual wave observations from CG shore stations for CERC.

–Surface weather observations from CG ships and stations and upper-air observations from six mid-ocean stations, for ESSA.

–Overflights of the Continental Shelf with airborne infrared radiation thermometers to map sea-surface temperature for the Bureau of Sports Fisheries and Wildlife (Department of the Interior).

At least half of the incoming merchant vessel weather reports are received at Coast Guard radio stations, from which they are relayed, via teletype, to ESSA.

Much of the Coast Guard data collection capability lies in its major vessels. In addition to two oceanographic ships, 35 ocean station vessels and eight polar icebreakers are equipped with standard oceanographic equipment. Two oceanographic vessels and one icebreaker are equipped with computers. Computers are planned for the remaining ships.

The four major routine data collection programs carried on by Coast Guard vessels are the ocean station program, the standard monitoring section program, polar oceanography, and the International Ice Patrol. Coast Guard ocean station vessels make routine surface and upper-air weather observations and daily oceanographic casts on four Atlantic and two Pacific stations. The standard monitoring section program consists of seasonal reoccupation of seven Atlantic and six Pacific sections. The location of the ocean stations and standard sections is shown in Figure 9. Data

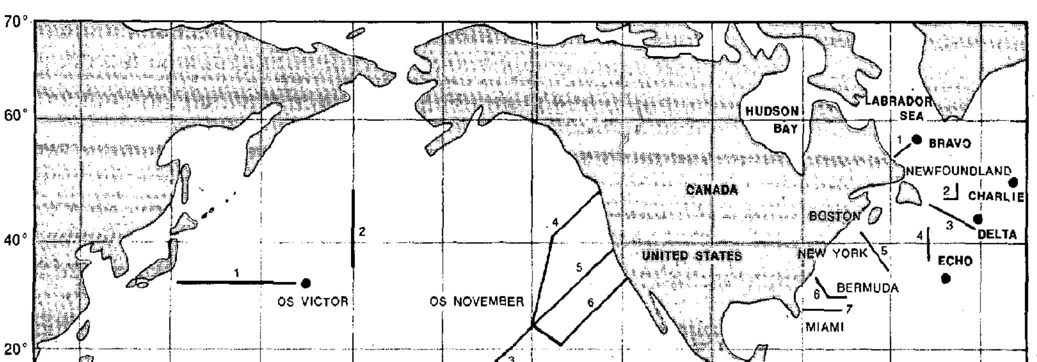

Figure 9. *Ocean stations occupied by Coast Guard ships. Meteorological and oceanographic data are collected routinely. Maps also show the "standard sections" along which hydrographic and oceanographic data are collected; sections are scheduled for revisit at least every three months.*

from both programs are transmitted in real time to support ASWEPS and fisheries forecasts.

Polar data collection is performed in both the Arctic and Antarctic by the eight icebreakers, which comprise the Federal fleet of this class of ship. Data is provided to the Navy and the oceanographic community. The International Ice Patrol oceanographic operations are conducted on and near the Grand Banks of Newfoundland, with research cruises into the Atlantic sub-Arctic regions.

Another source of real-time and research data is the Shallow Water Oceanographic Research Data (SWORD) System. The partially operational SWORD System consists of a network of Coast Guard coastal facilities. The complete system will include offshore light towers and associated buoy arrays, large navigational buoys equipped with environmental sensors, coastal stations, and light ships.

The Coast Guard's data processing and quality control capabilities are concentrated at its Oceanographic Unit (CGOU) in Washington, D.C. As more computers are made available to operating units, the data collection units will be able to perform their own data processing, and disseminate more data directly. Processed data is either transmitted directly from data collection units or from CGOU, over the Coast Guard radio and landline communications network to users and the National Oceanographic Data Center.

To promote maritime safety, the Coast Guard cooperates with ESSA by broadcasting coastal marine weather information to shipping and other maritime users at 31 locations. These broadcasts were established to fill gaps in commercial radio station coverage and constitute a major effort by the facilities concerned. Broadcasts are scheduled at 6- or 12-hour intervals, with warnings of hazardous conditions transmitted upon receipt and repeated periodically. The broadcast texts are prepared by ESSA and delivered to the nearest Coast Guard communications office. There are 163 Coast Guard lighthouses, lifeboat stations, lightships, and other facilities participating in the Coastal Warning Display System. The Coast Guard provides support to existing data platforms in stationing, servicing, and relieving activities. The Coast Guard also conducts ice reconnaissance on the Great Lakes.

D. Department of the Interior

Environmental monitoring and research and development programs to provide the rationale for prediction are extensive, and include work of the Bureau of Commercial Fisheries and Bureau of Sport Fisheries and Wildlife of the Fish and Wildlife Service, the Federal Water Pollution Control Administration, and the Geological Survey. The role of environmental monitoring in Interior is to provide for:

–Prediction of abundance and distribution of fishery resources

–Pollution detection and control

–Water resource development and appraisal

–Detection of geologic processes

–Measurement of pesticide and radionuclide concentration in living marine resources.

The Department's programs are oriented toward the missions listed above. The Department recognizes the marine environment as a unit and encourages the study of meteorological and physical oceanographic and biological processes as a system to facilitate understanding of the mechanisms involved in the biological productivity of the world oceans and their temporal and spatial variations.

1. Bureau of Commercial Fisheries (BCF)

The objective of Interior's fishery oceanography program is to determine, for each major fishery, how the environment affects the abundance and distribution of the species and how changes in significant environmental features can be predicted. Because of the many different habitats of the fishery resources ranging from the tropical near-surface schooling tuna to the bottom-dwelling king crab of the boreal latitudes and to the estuarine-dependent shrimp, the Department's oceanographic interests cover an extensive geographic range. Consequently, the supporting oceanographic research and development programs are equally extensive, including studies of:

–Dynamics of the North Pacific, Pacific Equatorial, and California Current Systems by using drift buoys, research vessels, and associated sensors.

–North Atlantic and Tropical Atlantic circulations, with the latter of special interest for understanding variations in abundance and distribution of tuna in the equatorial Atlantic.

–Intrusions and mixing of water masses over the Continental Shelf off the eastern United States, including the circulation in the Gulf of Maine and the meandering of the Gulf Stream.

In some fisheries, these studies have led to operational forecast programs. The BCF Honolulu Biological Laboratory now makes annual availability predictions of skipjack tuna in the Hawaiian area on the basis of temperature and salinity data taken at Koko Head, Hawaii. The BCF Fishery-Oceanography Center at La Jolla, California analyzes historical California Current data and sea-surface temperatures of the North Pacific to prepare annual predictions of locations where albacore tuna will occur during June and July. In addition, monthly and 15-day sea-surface temperature charts are compiled from information supplied by the Navy, by ESSA, and by industry sources. These charts are distributed in published form to enable fishermen to select fishing areas. An ocean information reporting service furnishes day-to-day information by radio to local and high-seas tuna vessels. (A sample forecast is appended to this report.)

Other forecasts by the Bureau of Commercial Fisheries, some in cooperation with international commissions and the States, include prediction of abundance of shrimp in the Gulf of Mexico, groundfish and sea scallops off the New England coast, menhaden off the United States East Coast, red and pink salmon in the Pacific Northwest, halibut in the Pacific Northwest, sardine off Baja California and California, and crab off California.

Tuna forecasts are essentially distribution or availability forecasts and are based primarily on empirical relationships derived between fish populations and environmental conditions. Forecasts for other species are based primarily on the relative strength of year-classes, estimated by the number of young that are sampled several months prior to the beginning of fishing operations.

2. Bureau of Sport Fisheries and Wildlife (BSF&W)

The Bureau of Sport Fisheries and Wildlife carries out extensive research and development programs similar to those of the BCF to determine relations between sport fisheries populations and the environment to develop the scientific basis for forecasting. These studies are carried out at the BSF&W marine laboratories at Tiburon, California; Sandy Hook, New Jersey; and Narragansett, Rhode Island.

BSF&W does not make any operational oceanographic forecasts, but does conduct monthly sea-surface temperature surveys, using an airborne infrared thermometer, for the Atlantic Coast (Cape Cod to Cape Henlopen) and for the Pacific Coast (southern and central California, northern Oregon, and Washington). This survey program is carried out in cooperation with the Coast Guard and Navy.

3. Federal Water Pollution Control Administration (FWPCA)

The Federal Water Pollution Control Administration has developed mathematical models applicable to forecasting the impacts of wastes on the estuarine environment. The models are for the most part general in nature and thus applicable to many special situations. Examples of major applications are analysis of the impact of inland wastes on the San Francisco Bay-Delta area in California and analysis of organic and salt water intrusion effects on the Delaware Estuary. These activities are not covered in detail in this report because of their relatively local nature and non-real-time application, as well as the coverage provided by another report of this panel. Although these predictive tools are applied only in planning or emergency situations, FWPCA has the technical capability to forecast estuarine quality conditions where required.

4. Geological Survey

It has been necessary to restrict attention in this summary to oceanographic and marine meteorological activities. The Commission has noted the need for concerted action in regard to the Nation's estuaries, and we have addressed this subject at length in another report. For forecasts of environmental parameters in the estuaries, river flow data is required, in addition to oceanographic parameters. (For a more detailed description of the data requirements, and the interface between estuarine and larger-scale prediction programs, see Chapter 7.) Although river flow monitoring and prediction activities were nominally considered outside our purview, we do wish to note the major programs of the Geological Survey in the Department of the Interior, and ESSA's hydrology program in the Department of Commerce.

The Geological Survey operates more than 200 stations at which river inflow to estuaries and other coastal waters is measured; it obtains water quality measurement at more than 100 coastal stream sites. The Survey is engaged in the measurement of sediment discharge into, and of sediment movement within, many estuaries. It has developed an operational technique for calculating the flow in an estuary from records of tidal stages and other data. Programs conducted in cooperation with several States provide for measurement of several physical parameters in estuaries and near-shore zones. ESSA operates additional river flow stations and also uses data from Geological Survey stations; it also uses rainfall and other meteorological data to provide daily river flow forecasts for the Nation. Many local and State agencies operate similar programs.

IV. INDUSTRIAL ACTIVITIES

The principal industrial oceanographic forecasting activity is in ship routing, as extensions and/or principal activities of the meteorological forecasting services provided by industrial consultants. At present, firms in San Francisco, New Orleans, Houston, New York, Baltimore, and Washington provide ship-routing forecasts. The west coast operation prepares forecasts for Atlantic and Pacific crossings and involves communications with the ships during transit. The New Orleans firm specializes in forecasts for tugs towing offshore platforms for oil exploration and provides services for the Gulf of Mexico, transits to Africa, Europe, and Hudson Bay. In the latter case forecasts include ice conditions. Several of these commercial operations include specially tailored services, with the forecasters dealing not only with a shipping line but directly with the masters of the ships for whom they are forecasting. In certain cases their forecasts may be used, not only for routing of the ships, but to determine such other factors as freight loading, harbor conditions, etc.

In addition to industrial ocean wave forecasting/ship routing activities, there are isolated instances of "one-man" oceanographic forecasting programs in private industry. Several construction firms make use of forecasts of near-surface thermohaline conditions, sea-swell-surf conditions, etc. provided by consultants on an "as-needed" temporary basis.

In general, there appears to be little industrial activity in forecasting thermohaline structure, tide, current, or ice movement. However, several private meteorological-oceanographic consultants possess the capabilities necessary for producing detailed, small-scale, local forecasts of these and other parameters. A group of oil companies is embarking on a major data collection program in the Gulf of Alaska to provide information on extreme conditions for oil-drilling platform design criteria and mean values for logistic planning.[9]

V. OTHER NATIONS

Major foreign oceanographic forecasting activities are government-sponsored and most frequently operated to meet military requirements. For example, the Japanese Maritime Self-Defense Force provides operational forecasts of thermohaline structure (including sea-surface temperature and thermal layer depth) and wave conditions for Japanese waters.

The Japanese issue fishing forecasts and report catch data and related environmental data on a world-wide basis. Fish catch forecasts are made seasonally and for shorter periods. Many ships in the fishing fleet are instrumented to record environmental parameters, and these data are reported to home bases. The dissemination of forecasts is implemented by the "All Japanese Federation of the Fisheries Association."[10]

The British Naval Weather Service has an operational thermal structure forecasting program similar to ASWEPS. The Canadian Ocean Services for Defense, operating out of the Bedford Institute for Oceanography, Nova Scotia and Nanaimo, British Columbia, provides operational, long- and

[9] Blake, F. G., testimony at panel hearing.

[10] Food and Agriculture Organization of the United Nations, Advisory Committee on Marine Resources Research, *Report of ACMRR Working Party on Fisherman's Charts and Utilization of Synoptic Data,* FAO Fisheries Reports No. 41, Supp. 2, Rome, Jan. 16-21, 1967.

short-term forecasts of several parameters (including thermohaline structure, wave conditions, and sea ice conditions) in support of naval operations. The Soviet Union supports a large and comprehensive oceanographic forecasting effort oriented toward military operations.

The U.S.S.R. has a well-developed operational sea ice prediction system for Russian Arctic and sub-Arctic seas, probably the most advanced in the world. Canada, through both the Ocean Services for Defense and its Ice Forecasting Central, produces operational long- and short-term sea ice forecasts for Canadian Arctic seas (Beaufort Sea, the waters of the Canadian Archipelago, Hudson Bay, Baffin Bay, Davis Strait, and the Labrador Sea) as well as for areas of the North Atlantic Ocean.

Other nations also produce small-scale, local sea ice forecasts. Germany forecasts ice in the Baltic Sea, Finland in the Gulf of Finland, and Great Britain in Icelandic waters (Davis Strait, Norwegian Sea, and Greenland Sea) in support of British fishing operations.

Another major area of international oceanographic forecasting is in the field of tide and tidal current predictions. All major maritime nations produce operational tide (and often tidal current) predictions for their own use. Smaller nations receive necessary tide and tidal current predictions from the major maritime nations.

The United States maintains a working liaison with nations active in oceanographic forecasting and exchanges procedural information with them. Excellent cooperation exists among British, Canadian, and U.S. forecasting activities, as witnessed by frequent conferences, symposia, and joint forecasting activities. With minor exceptions, the United States has operational oceanographic forecasting programs comparable to, or more advanced than, any now existing in other nations.

The activities of the Federal Government in marine environmental prediction, described in Chapter 3, have tended to develop into a military system and a separate civil system, with considerable sharing in data collection. To continue to insure responsiveness to rapidly-changing military requirements as well as to provide adequate priority for civil needs, the Nation must establish suitable organizational arrangements. Our recommendations on this issue are presented in detail in Chapter 7.

In this chapter we assess the present capabilities for forecasting oceanographic and certain meteorological conditions.

I. OCEAN TEMPERATURE STRUCTURE

The panel has reviewed temperature-structure forecasting programs and received detailed briefings from the Navy, and it finds that this program provides operationally useful forecasts. On the basis of our evaluation, however, we have concluded that present capabilities fall far short of providing the accuracies required in forecasting thermal structure in the ocean. Advanced processing and forecasting techniques are applied to the available data, but progress is limited by the relatively small number of observations and by limited understanding of the pertinent physical processes.

II. SEA-STATE

Techniques for sea-state forecasting[1] were given significant impetus during World War II and have since been developed, principally by the Navy, to yield useful operational forecasts. The ability to forecast ocean-wave generation is seriously limited by the relatively sparse wind data now reported over the oceans. Verification of forecasts and improvement of theory are also hampered by a lack of wave spectrum data. The number of wind observations could be increased by expanding the ship-of-opportunity program. The ability to observe the low-level wind structure in the atmosphere from a ship would also provide a significant contribution.

[1]Sverdrup, H. U. and W. H. Munk, *Wind, Sea, and Swell: Theory of Relations for Forecasting,* 1947, U.S. Navy Hydrographic Office, Washington, D.C.

III. OPPORTUNITIES FOR IMMEDIATE IMPROVEMENT

We have noted, in our review of these programs, that opportunities exist for immediate improvements at relatively modest cost. The present ability to analyze and predict sea surface conditions is limited by the scarcity of surface ocean and weather observations. The two cases cited above are examples. As described in Chapter 2, this data "gap" is also a severe limitation on our ability to predict the weather.

Captain Paul Wolff, Commanding Officer of the Navy's Fleet Numerical Weather Central, has described the availability of physical oceanographic data in a recent report[2] (amplified in his testimony before the panel):

about 1,000 unique ship reports (which describe weather conditions plus sea state and sea temperature measurements), 125 ocean temperature versus depth soundings (bathythermographs), and fifteen shipboard radiosonde soundings (which contain pressure, temperature, humidity, and wind measurements in the atmosphere) every twelve hours.

These figures refer primarily to the Northern Hemisphere, and would only be changed in a small way if Southern Hemisphere reports were included. By comparing these data with results of a survey reported by the World Meteorological Organization (WMO)[3] as well as other estimates it appears that the vast majority (probably greater than 90 per cent) of the "unique ship reports" are made by merchant ships cooperating in the international weather observing program of the WMO (see Chapter 8). Figure 10 shows the geographical

[2]Wolff, Capt. Paul M., USN, 1967: Technical Note No. 32, *Oceanographic Data Collection,* Fleet Numerical Weather Facility, Monterey, California.

[3]Hanzama, M., and T. H. Tourier, 1968: *System for the Collection of Ships' Weather Reports.* World Weather Watch Planning Report No. 25, World Meteorological Organization, Geneva, Switzerland.

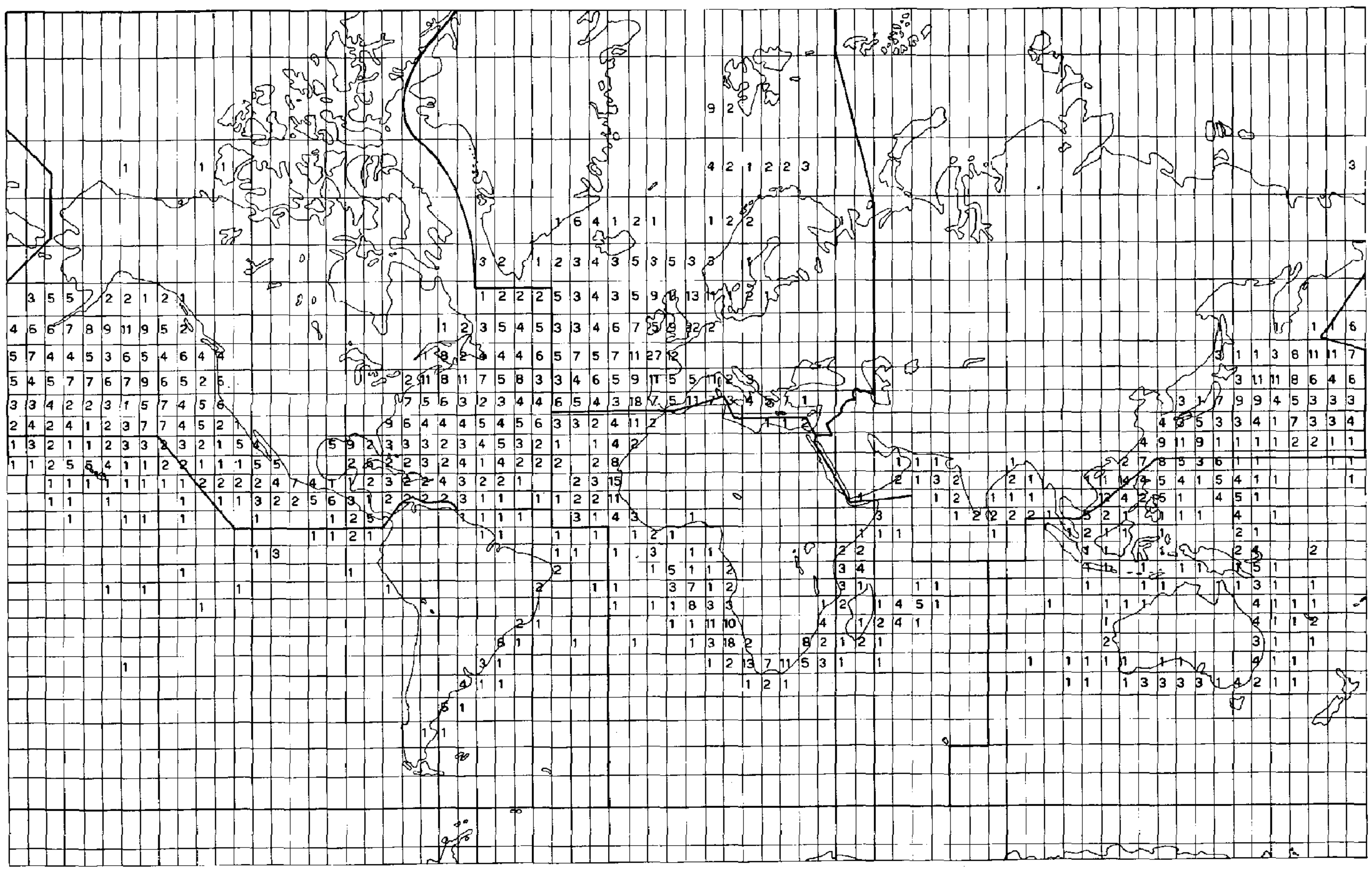

Figure 10. *Geographical distribution of mean daily number of merchant ship weather reports for five alternate days during the period Sept. 1-9, 1967. (Hanzama, M., and T. H. Tourier, System for the Collection of Ships' Weather Reports, World Weather Watch Planning Report No. 25, World Meteorological Organization, Geneva, Switzerland, 1968)*

distribution and average number of daily ships' weather observations during a five-day period.

Wolff also estimates that for a given day there are seven ships at sea for each ship's observation received. Clearly, more data could be received by increasing the number of ships in the WMO cooperative program. The ship-of-opportunity program, through which the bulk of ocean weather and sea-surface temperature data is now obtained, can be expanded at low cost.

ESSA reports that, of the merchant vessel reports received directly in the United States, about a third are made directly to U.S. coastal radio stations and processed by commercial channels at an average cost of about three dollars per report; the remaining two-thirds are initially received at Government-operated communications facilities, including the Coast Guard's, and retransmitted at no additional cost to the Government. It is estimated that additional sets of on-board observing equipment could be purchased at about $800 per set. There are some additional administrative expenses, such as those incurred in providing checks of instruments by Port Meteorological Officers. The U.S.-owned ships that participate in this program are not reimbursed for taking the observations, although some foreign governments do reimburse their ships.

Many of these observations are first reported by radio to overseas communications centers, and then retransmitted to the United States via international meteorological communications channels. Additional reports are submitted by mail, primarily to enhance the long-term climatological data bank as opposed to real-time data processing. The elaborate administrative mechanisms for the conduct of this program are well established. (See Chapter 8 for a discussion of the WMO role in this program.) The reports are presently limited to standard meteorological observations, surface ocean temperature, and an estimate of sea state.

Vast areas of the world oceans are not included in the coverage of this program, primarily areas not covered by merchant shipping. Figure 12

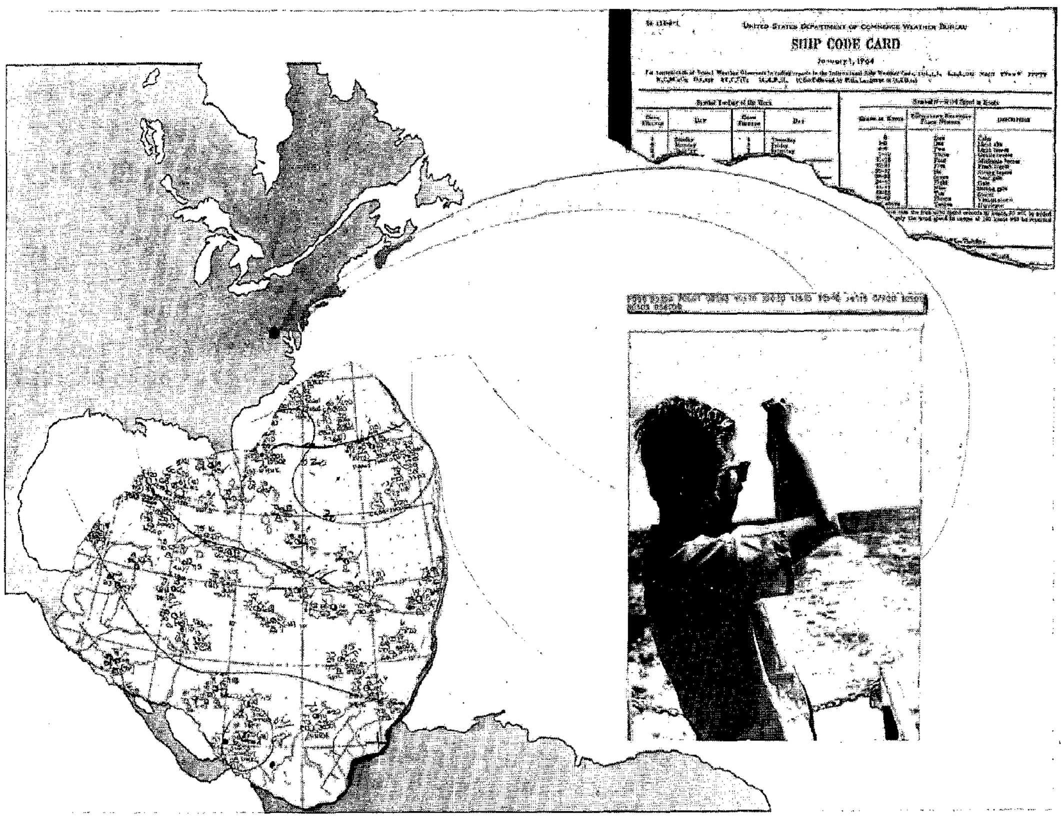

Figure 11. *Schematic representation of use of weather data collected by merchant ships of opportunity. Insert (upper right) shows a portion of standard instructions for coding these data by merchant vessels. Lower right photograph shows a member of ship's company taking wet and dry bulk temperatures, part of the data encoded in the sample teletype message. Map on lower left shows a portion of a surface weather map on which this and other merchant ship weather reports are plotted.*

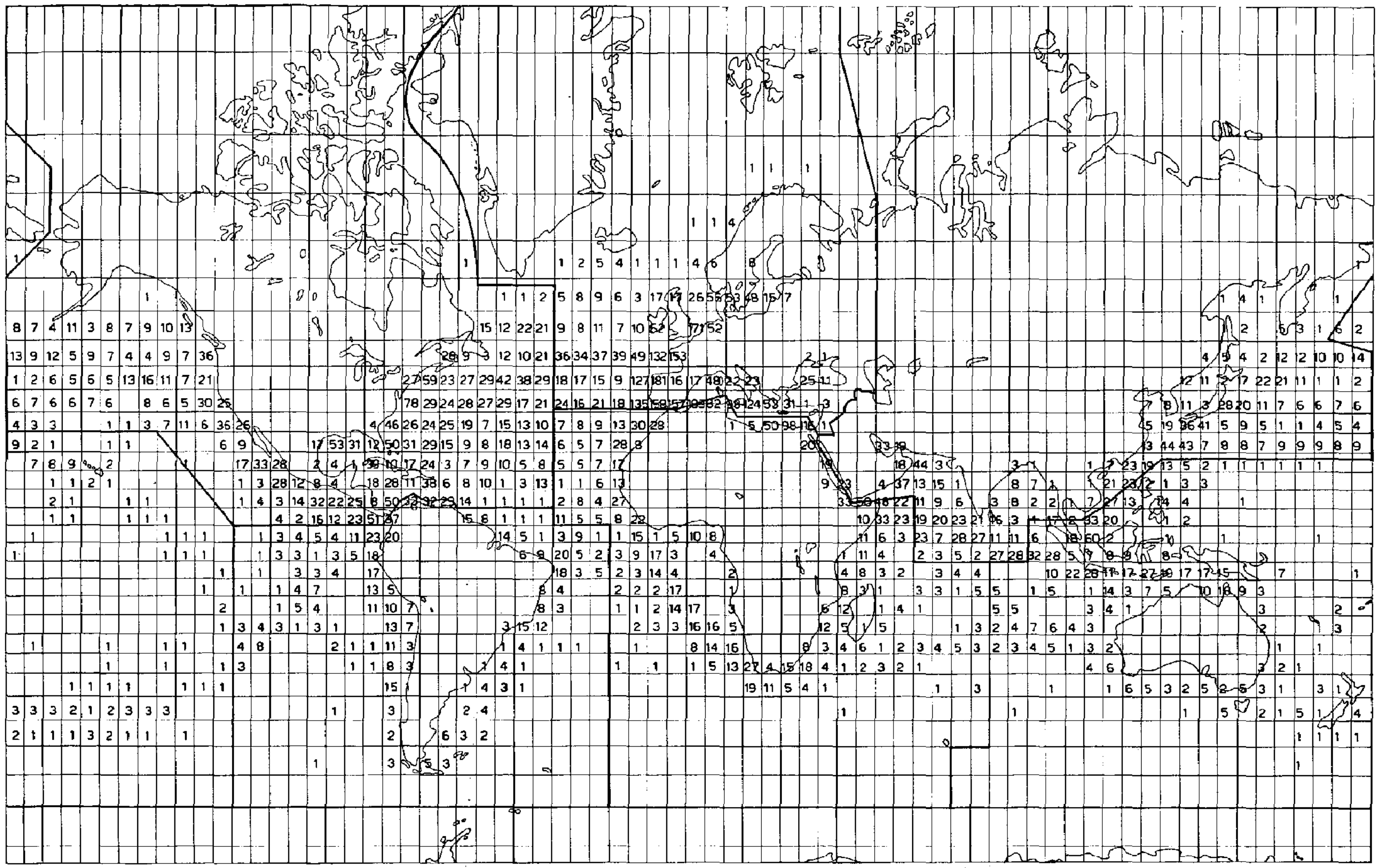

Figure 12. *World merchant ship density on June 12, 1964. (Hanzama, M., and T. H. Tourier, System for the Collection of Ships' Weather Reports, World Weather Watch Planning Report No. 25, World Meteorological Organization, Geneva, Switzerland, 1968)*

shows this graphically; it indicates world merchant ship density on June 12, 1964, and clearly demonstrates that there are great areas of the world oceans that are not covered by merchant ships in appreciable numbers, or in some areas at all.

The WMO is looking into the possibility of obtaining reports from world fishing fleets, some of which operate, at least for part of the year, in areas not frequented by merchant shipping.[4] One direction for expansion of this program should therefore be the inclusion of ships not now participating, particularly fishing fleets such as those of Japan, Taiwan, and Korea.

As noted above, the Navy's program in the analysis and prediction of near-surface ocean thermal structure is data-limited. Needed data could be provided by additional expendable bathythermograph soundings (this equipment is described in Chapter 5). Of the 125 bathythermographs reported by Wolff the majority are provided by naval vessels, with some reports from ships of opportunity in a cooperative Navy-Bureau of Commercial Fisheries program. Additional ocean temperature data could be collected by expanding these programs; this effort should be tailored to fill in at least some of the gaps in data coverage. Work should continue on the development of automatic data encoding and transmitting devices. (See Chapter 5.) Although the expendable bathythermograph probe is lost in the data collection, quantity production has reduced the cost to approximately $20 per instrument. The installation of a relatively simple on-board launcher and data recorder is estimated to cost approximately $5,000.

In addition to the temperature data in the ocean's near-surface layers, broader data coverage is required in the lower layers of the atmosphere; this is now limited to the relatively few radiosondes launched from ships. The radiosonde observations are taken from the Coast Guard Ocean Station Vessels, as well as by about 15 ESSA teams aboard a limited number of MSTS, ESSA, and merchant ships in the Pacific. Rough estimates indicate that the equipment expended in a shipboard radiosonde program costs about $40 per observation, with an additional cost of about $100-150 for personnel. Additional sets of shipboard receiving equipment which interprets the data transmitted by balloon-carried instrumentation would probably cost (at today's prices) somewhat less than $10,000 per installation. It should be noted that a principal manpower cost in connection with this program is "dead time" when a merchant ship is in port; expansion of the program to permit efficient transfer of the men from ship to ship would reduce the labor cost per observation.

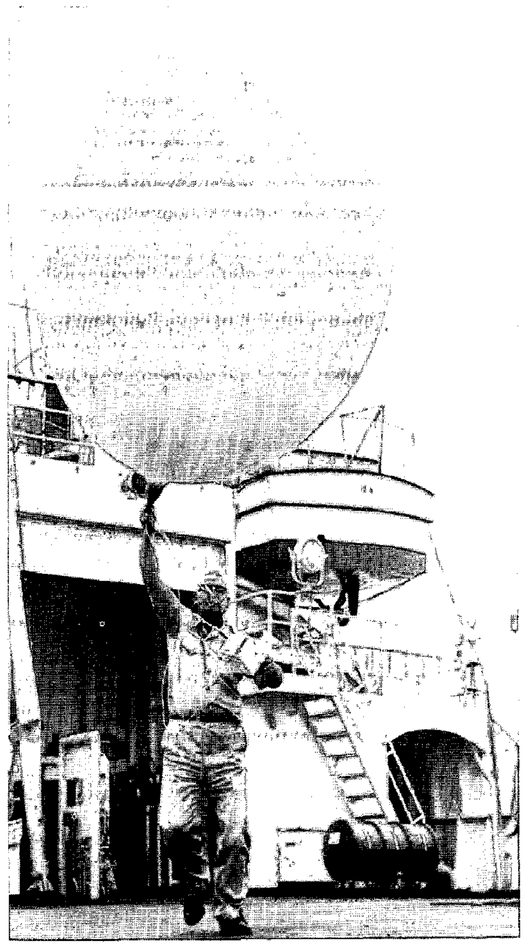

Figure 13. *Release of radiosonde aboard ship. (ESSA photo)*

In certain coastal areas including the Gulf of Mexico, platforms have been erected for the extraction of oil and natural gas; at present a limited number of offshore platforms are instrumented to provide environmental data for major forecasting programs. For example, ESSA's New Orleans office regularly receives standard meteorological data

[4] 1966: *Meteorological Observations from Mobile and Fixed Ships,* World Weather Watch Planning Report No. 7, World Meteorological Organization, Geneva, Switzerland.

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from three oil-drilling platforms in the Gulf of Mexico. Oil companies collect various data in support of the development of engineering design criteria. There is a critical need for wave-height data from these offshore installations. Additional platforms could be instrumented economically. Plans are already underway to instrument additional Coast Guard navigational buoys and offshore light stations.

Recommendation:

The ship-of-opportunity program should be expanded immediately to provide more surface ocean and weather reports, additional ocean temperature structure data, and more wind soundings. Ships operating in regions not covered by major merchant vessel trade routes should be included. Additional instrumentation should be placed on offshore platforms.

When the distribution is considered, in addition to the number of observations, it is even clearer that improved ocean data coverage is needed. Initially, expanded programs for collecting such data by ships-of-opportunity, with existing technology as recommended, would constitute a significant improvement. Further technical developments to improve instrumentation are under way. (See Chapter 5.) In the final analysis other alternatives must also be pursued to provide adequate data from those areas of the world's oceans not routinely visited by merchant or fishing vessels, at an acceptable cost. This is the challenge posed to technology, and to which buoy development and satellite sensor developments are addressed (See Chapter 5.)

IV. OCEAN CURRENTS

Present operational surface current forecasting is essentially limited to "persistence" or "climatology." At this point we can simply state that expanded research efforts are required. But the reader is referred to Chapter 6, Scientific Limitations, where this subject is addressed further.

V. TSUNAMI

The panel has evaluated the tsunami warning program and has noted the significant progress since its inception in 1948. The present ability to forecast tsunami arrival times at Pacific Ocean locations appears to be adequate, but runup forecasts are often grossly in error. The Tsunami Warning System performance is limited by lack of sufficient near-shore and deep-ocean tidal and seismic data, as well as inadequate theoretical understanding of energy-focusing processes. Additional instrumentation is required in the Pacific, possibly at island stations, and further development of deep-ocean tidal instrumentation is needed.

To achieve the required coverage, ESSA estimates that the number of tidal stations in the network should be tripled (from 40 to 120); the number of seismic monitoring stations should be increased by about 50 per cent (from 15 to 25). The present warning doctrine provides magnitude, location, and time of the originating disturbance, to give some measure of the expected threat.

Recommendation:

Steps should be taken to expand the present tide and seismic monitoring network in the Pacific basin. International communications from South America and the Southwest Pacific should be improved. Additional research on tsunami generation and runup problems should be instituted.

VI. HURRICANE

The operational hurricane warning system described in Chapter 3 performs adequately within present constraints. In part the system's satisfactory performance has been due to the excellent response of the citizenry in the hurricane-prone areas of the country (principally Florida and the Gulf Coast), as well as the cooperation of the mass communication media. The ability to track existing hurricanes by satellite, aircraft, and shore-based radar is satisfactory. The earth-synchronous satellite (ATS-3) in a "stationary" position over the mid-Atlantic can provide a picture every 20 minutes showing the major hurricane areas of the Gulf of Mexico and western Atlantic; it will provide a major assist in hurricane tracking. However, improvements in our capability to forecast hurricane development and motion, and the storm surge are still urgently required.

The scope of the operational forecasting activities, as well as each hurricane season's data collection program are limited by present budget levels.

Hurricane data collection, much of it performed by Navy, Air Force, and ESSA aircraft, must be augmented by additional high performance aircraft with up-to-date instrumentation. In addition, there is a continuing operational requirement for more detailed meteorological data over the Caribbean and the Gulf of Mexico, specifically:

–The network of upper air sounding stations in the West Indies and the Carribean should be improved.

–Additional routine air reconnaissance to the African coast should be instituted.

–Upper-air wind measurements should be obtained from merchant ships in tropical areas.

–Early deployment of buoys to the east of the Lesser Antilles to provide surface weather data should be accomplished.

The data collected should be used not only to support day-to-day forecast activities, but also to test mathematical models and hurricane-modification hypotheses.

Recommendation:

The Hurricane Warning Service requires expanded data networks. This Service should be accorded high priority to take advantage of the latest technical and operational developments. Additional research is needed to improve our capability to forecast hurricane development and motion.

VII. ICE

In reviewing the programs described in Chapter 3, we find that aerial iceberg observation services are useful and effective with regard to ship routing in the North Atlantic, but capabilities of predicting iceberg motion and sea ice distribution are still limited. A fundamental lack of understanding exists in regard to the transfer of heat and stress from the air above and the water below to the ice interface. Predictions of the subsequent motions and deformation of sea ice require an improved capability to forecast the wind near the ocean surface. Since the most severe stresses are imparted to the ice during periods of darkness and/or severe storms, with thick clouds prevalent, imagery acquired by airborne and satellite remote sensors (see Chapter 5) is a requirement for rapid advances in our understanding of sea ice dynamics.

Recommendation:

Research efforts to improve sea-ice forecasting should be expanded; efforts in remote sensing of glacial and sea ices, especially in sensors that can penetrate clouds, are encouraged. Further basic research in energy transfer through the air-ice-water media to yield improved models of the formation, growth, drift, deformation, and disintegration of different ice types is required.

In recent years significant advances have been made in data-collection devices and their associated platforms. Application of these advances, together with technology now under development, promise dramatic improvements in our ability to observe the total environment, process and transmit the resulting data. Extrapolations of present technology make it appear feasible that the future environmental monitoring and prediction system will provide automatic processing of data communicated (possibly relayed from satellites) from over the entire globe in real time. Computers would test data reliability. Some environmental sensors would be in near-continuous operation, permitting computer systems to operate in a continuously updating mode. At regular intervals the system would produce required forecast charts and other processed data which would be disseminated to users. The system could also be interrogated to yield specialized forecasts on demand. New display devices will supplant the present printed chart, telephoned forecast, and personal briefing.

It is not yet possible to stipulate the complete and detailed composition of the system; the evaluation of the proper mix of platforms and instruments, based on performance, cost, and reliability, is one that must be addressed (cf. Chapter 9).

In this chapter several current efforts in the technology associated with environmental monitoring are reviewed.

I. FIXED STATIONS–BUOYS

Fixed stations, on which to install automatic instrumentation, include buoys, islands, radar towers, oil rigs, and ocean bottom facilities. Some fixed stations offer a relatively inexpensive platform for the collection of marine data. Earlier in this report the panel has recommended that additional offshore oil-drilling platforms be instrumented. Towers extensively instrumented for research purposes[1] have adequately demonstrated feasibility.

Fixed stations now routinely collect data that includes temperature, acoustics, salinity, sea state, currents, and near-sea weather. Additional measurements are technically feasible and may be included in future programs; these include oxygen; nutrients such as phosphates, nitrates, and nitrites; chlorophyll; bioluminescence; transparency; and a measure of biomass by acoustic or photometric techniques.

Because of the special current interest and possible wide application, we have concentrated here on buoy development; sensors developed for buoy applications are also useful for other platforms. Several recent developments will be briefly discussed and the present status of the field surveyed; the panel has not attempted a comprehensive review of the field since recent reports[2] present a thorough description of current capabilities and design considerations.

Buoy instruments to sense pressure, temperature, salinity, sound velocity, current speed and direction are now generally available. Basic measurements are converted into electrical impulses for transmission. Reliable transmission of the data from the platform to a shore station still requires further test and evaluation. The ocean platform typically consists of the flotation hull, power supply, mooring, and aids to navigation. It is generally recognized that extensive efforts are still required in the development of reliable anchors, moorings, power supplies, and hulls. The buoy system, to be operationally useful, must be capable of rough handling and easy serviceability.

Support may include ships for routine service as well as on-station replacement, shore stations to support the service ships, communication stations to provide the transmission link, and associated training, repair, and supply support. For an effective large-scale system, it will be necessary to consider the design of the service ships and the

[1] LaFond, E.C., *The U.S. Navy Electronic Laboratory's Oceanographic Research Tower; Its Development and Utilization.* Research and Development Report, NEL/Report 1342, Dec. 22, 1965.

[2] "A Study of the Feasibility of National Data Buoy Systems"–Final Report, July 1967. TRC Report 7485-256, Prepared for the U.S. Coast Guard under Contract No. TCG-16790-A; Transactions, 2nd International Buoy Technology Symposium/Exposition; Sept. 18-20, 1967. Washington, D.C., Marine Technology Society.

shore support facilities. Overall costs are greatly influenced by the maintenance requirements.

A. Navy Developments

The Navy has invested considerable effort in development of automatic reporting oceanographic and meteorological buoys.[3] One is the 20-foot long, 10-foot beam boat type "NOMAD" (Navy Oceanographic and Meteorological Automatic Device), on which are mounted sensing devices for air temperature, wind, pressure, and sea

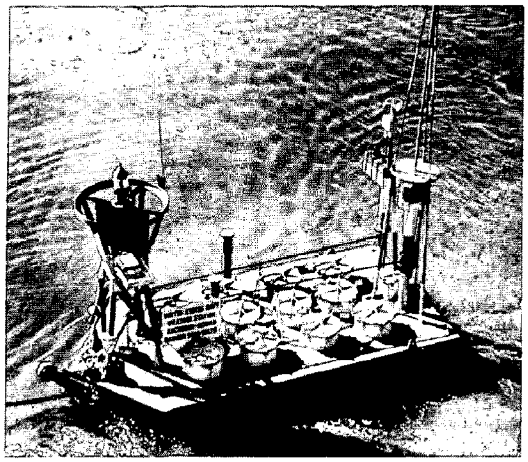

Figure 14. *Navy's NOMAD (Naval Oceanographic and Meteorological Automatic Device). This buoy, the N3S, is powered by the SNAP-7D nuclear power device and is deep moored in the Gulf of Mexico. (Navy photo)*

temperature. The buoy has been successfully moored at a depth of 11,000 feet. Underwater temperatures and pressures to 1,000 foot depths have been measured and transmitted to shore stations. A device to measure sea state is under development. Tests have been conducted of a version powered by the SNAP-7D nuclear power generator, engineered for a two-year service interval and an estimated 10-year lifetime.

The Navy has also sponsored the development of a small-scale NOMAD, with dimensions about one-half the original. Its quantity cost is estimated at about one-half the cost of the larger buoys.

The so-called MONSTER buoy, now referred to as the "Ocean Data Station," 40 feet in diameter, has been developed primarily for oceanographic

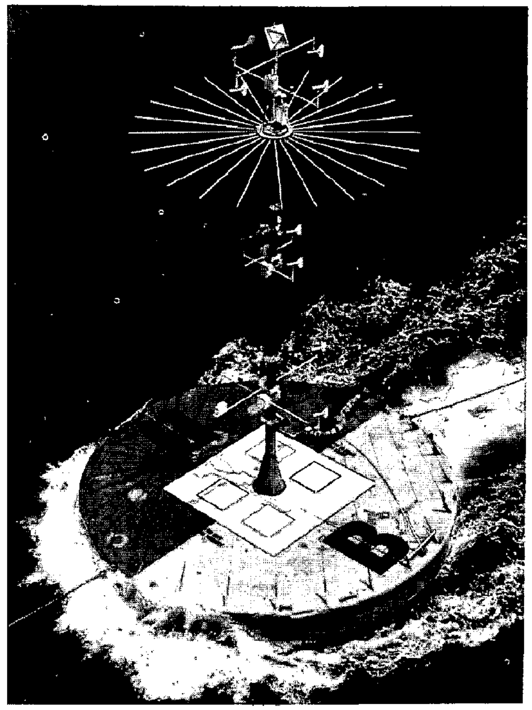

Figure 15. *The Monster buoy (Ocean Data Station) leaving San Diego on July 29, 1968, under tow, to a test site in the North Pacific. The buoy is now successfully moored. (General Dynamics photo)*

research, but is capable of measuring and transmitting surface meteorological data. It can remain unattended in the deep ocean for up to one year. Present plans call for two buoys to be on station in the North Pacific for approximately a year beginning in the summer of 1968, as part of an air-sea interaction experiment. Meteorological and oceanographic data will be transmitted to shore stations; satellite relay of data will also be tested.

The Navy deployed a network of buoys in the "Navy Acre"–an area bounded by 33°N-34°N and 73°-74°W; during the period September 1966 - early 1968. Several buoy types were included, with considerable success reported for the NOMAD; its mooring and communications checked out. Some difficulty was experienced in getting data from the submerged oceanographic sensors. At present two operational NOMAD buoys are on station in the Gulf of Mexico.

B. ESSA Developments

The ODESSA (Ocean Data Environmental Science Services Acquisition) System consists of two main instrument assemblies. The first is the

[3] See the following reference for a non-technical review of the Navy's buoy developments: Mottern, Captain R. E., USN, E. F. Corwin and A. F. Pyle: The Meteorological Buoy Programme of the U.S. Navy. *The Marine Observer*, Vol. XXXVII, 1967, pp. 178-185.

receiving station and console; this equipment as well as the transmitting-receiving equipment and auxiliary read-out equipment, may be located aboard ship or at a shore station. The second is the instrument moorings, which consist of the surface buoy (receiving, transmitting, recording and control electronics with power supply) and subsurface digitizer sensor packages. The sensors measure current speed and direction, water temperature, conductivity (salinity), and the depth of the measurement. The system has been operated with several buoys reporting to one ship. Recent tests have indicated that the buoy can successfully transmit its data via satellite.

ESSA has also gained some experience in the development of stable platforms—i.e., buoys that remain essentially fixed below the surface. In addition, ESSA is developing a low-cost buoy platform for instrumentation to be interrogated by satellite. A test platform was moored at station "ECHO" in the North Atlantic (35°N, 48°W) on May 23, 1968 at a depth of 14,000 feet, and remained in place until September 1968.

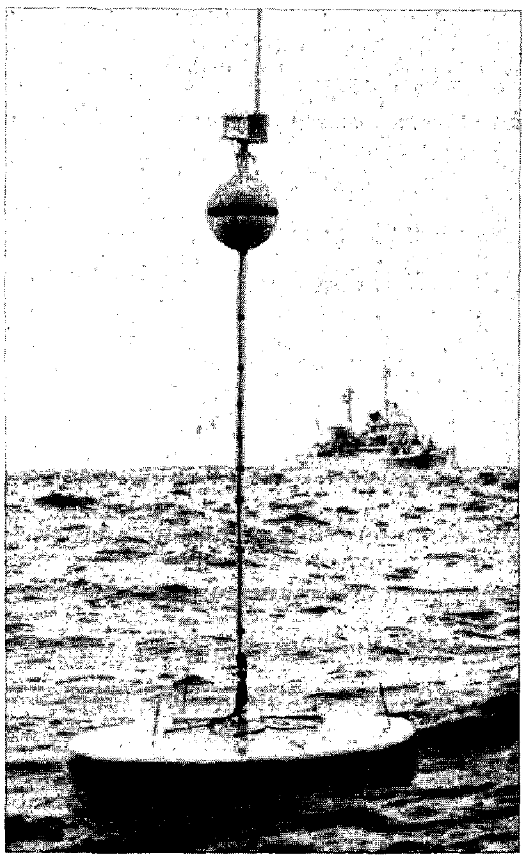

Figure 16. *Buoy under development at ESSA, after being moored at Ocean Station "ECHO" (35°N, 48°W) on May 23, 1968. In background is the Coast Guard cutter* Casco, *which assisted in the mooring operation. (ESSA photo)*

In the majority of buoy installations, the Coast Guard has cooperated by providing the mooring vessel, as well as considerable expertise.

C. National Program—Coast Guard

In 1966 the Ocean Engineering Panel of the ICO (Interagency Committee for Oceanography) recommended that a coordinated effort be undertaken in buoy development. A feasibility and state-of-the-art review, funded jointly by several agencies, was initiated. The Coast Guard acted as the executive agent for the study, completed in October 1967. The National Council on Marine Resources and Engineering Development, after reviewing the study, concluded that extensive research, development, test, and evaluation were required, leading eventually to the establishment of a National Data Buoy System. The Coast Guard, designated as the responsible agency for system development, established its National Data Buoy Systems Project Management Office in December 1967.

This system is viewed as one major subsystem of the total national marine meteorological/oceanographic data acquisition system, which has not yet been completely defined. It has been recognized that improved estimates of user benefits are required. Chapter 9 contains the panel's views in this area. The panel finds that adequate field testing should be required before a commitment is made to a full-scale operational system, because of its estimated cost. Experimental systems can be used to advance fundamental understanding of the partition of energy among different scales of motion, sea-air interaction, and ocean current dynamics (cited in Chapter 6 as major scientific limitations on our ability to predict oceanographic parameters). In particular, knowledge of scales of motion is vital for planning an operational buoy network; research experiments would also provide opportunities for hardware tests.

Operational buoys will provide platforms for sensors to collect biological and chemical data as well as physical parameters. Such employment of the platforms would provide valuable data at very small additional expense. Further, data describing biological degradation of moorings and hull structures will be required in developing planning factors for reliability and maintenance requirements.

Recommendation:

The National Data Buoy Development Program should be pursued vigorously. The Program provides for tests of alternative buoy hardware configurations, and different network spacings before a commitment is made to a major operational system; many of these tests can be conducted in support of major oceanographic research efforts (cf. Chapter 6).

II. MOVING PLATFORMS

Moving platforms for the collection of oceanographic data include ships and drifting buoys. Ships on oceanographic cruises have traditionally provided the bulk of oceanographic data for research. For the purposes of collecting data on a synoptic basis, i.e., at many points at the same time, the principal concern is with ships of opportunity—ships at sea for purposes other than oceanography that can collect useful data on a not-to-interfere basis.

Drifting buoys have long been used in such primitive forms as drift bottles to gather oceanographic information. Current technology makes it possible to use such buoys to collect data which would be transmitted via satellite relay.

A. Ships of Opportunity

Cargo, research, naval, and fishing ships offer relatively cheap sources of good data and should be fully exploited. Fully automated data collection devices are most desirable for fishing and commercial ships to permit their operation by personnel who are not technically trained. The equipment should not interfere with normal ship operations.

Obtaining useful data from the surface waters is relatively simple. It is technologically feasible to automate the monitoring of a number of important parameters including temperature, salinity, chlorophyll, and certain nutrients. The collection of samples through the use of towed devices such as the Hardy Recorder or by sampling through hull penetrations is also feasible. For more than 15 years the British have used the Hardy Continuous Plankton Recorder on North Sea steamers to obtain data valuable in managing the area's herring fisheries. Obtaining information about the subsurface waters from a ship underway is considerably more difficult. The recent development of the expendable bathythermograph (XBT), however, has pointed the way to the possibility of a family of sampling devices for use from ships cruising at high speed.

1. Expendable Bathythermograph

The needs for temperature-depth data in support of many operations, particularly the prediction of sound propagation conditions, have been discussed previously. Until recently, this data was collected by means of the mechanical bathythermograph, which records a temperature trace as a function of pressure. Use of this instrument has provided valuable insight into ocean temperature structure. The ship's speed was restricted during the lowering and retrieval of the instrument.

Figure 17. *Launching an expendable bathythermograph.*

Collection of these data is now facilitated by the development of the expendable bathythermograph which can be launched by a ship underway, with no speed restriction. Although the instrument is lost in collecting the data, quantity production has resulted in a reasonable cost. The probe remains connected to the ship by wire, running off two spools, during the data collection. Aboard the ship the data record provides a temperature depth profile. A small computer can process the data to provide a standard bathythermograph report in the form of a punched paper tape to be fed into the ship's radio transmitter.

The expendable bathythermograph has made it possible for naval ships to take temperature/depth observations while underway. The Navy's Fleet Numerical Weather Central collects some BT data from fishing and research ships in the Pacific, which are transmitted to the Bureau of Commercial Fisheries station at Scripps Institution of Oceanography. The Navy also collects some synoptic BT data in the North Atlantic from commercial vessels. The Bureau of Commercial Fisheries, in cooperation with the Navy, regularly obtains temperature structure data, by use of the expendable bathythermograph from the Matson Line freighter *Californian,* between San Francisco and Honolulu.[4] Tests have also been made using tuna fishing craft.

Ships of opportunity are also used in the collection of surface temperature, salinity, and current data using drift bottles in a BCF program in the western tropical Atlantic and Caribbean. The approach used in the expendable bathythermograph is adaptable for other sensor systems. Experiments have been conducted with a soil-bearing meter and a velocimeter. It is technically feasible to develop a family of instruments using a similar "free-fall probe" approach. In other cases the probe may be too expensive for expendable use or require actual samples for analysis. In these cases it may be feasible to employ a conductor cable of sufficient strength to recover the sensor. This permits the measurement of a number of other parameters.

2. Other Developments

Other recent developments that enhance the capability of a ship to collect vital data at sea are the several versions of the salinity-temperature-depth recorder (STD). One version is self-contained and battery powered; it records salinity, temperature, and depth data on a graphic plotter. This is a reusable instrument; another version records data on magnetic tape. A later model of this instrument transmits a signal to the ship by cable, where it is recorded on a paper graph.

Under preliminary development by the Navy is a portable oceanographic data collection "package" for use aboard ships of opportunity, with emphasis on development of an expendable temperature-salinity-depth unit.

Equipment to provide "winds aloft" economically from a moving ship is in an advanced state of development. Previous methods of tracking a radar target involved the measurement of elevation angles, requiring antenna stabilization. The new technique eliminates this requirement, and the antenna stabilization problem has been made tractable. The objective of this program has been to produce an instrument suitable for installation aboard merchant ships.

B. Drifting Buoys

Drifting buoys, long in use, have recently been proposed to achieve a grid spacing suitable for numerical weather forecasting. Floating buoys can be monitored from ships, shore, or by satellite.

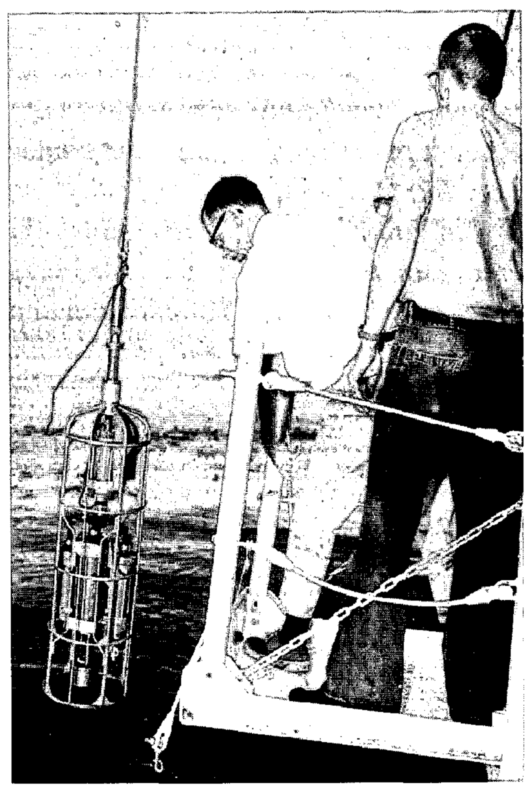

Figure 18. *Launching STD (salinity, temperature, depth) and sound velocity sensor. (ESSA photo)*

[4] An analysis of data collected in this program is contained in: Saur, J. F. T. and Dorothy D. Stewart, 1967: *Expendable Bathythermograph Data on Subsurface Thermal Structure in the Eastern North Pacific Ocean.* United States Fish and Wildlife Service, Special Scientific Report–Fisheries No. 548, Washington, D.C. 70 pp.

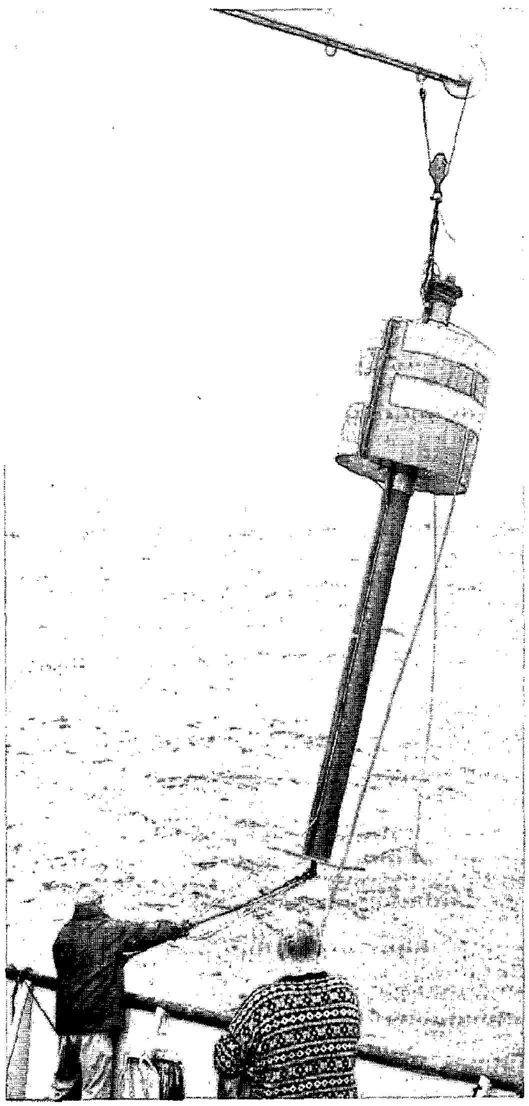

Figure 19. *Launching free-drifting buoy with temperature and salinity sensors in the Pacific, as part of BCF program. Data are transmitted to shore station by radio. (Bureau of Commercial Fisheries photo)*

The Bureau of Commercial Fisheries is using drifting telemetering buoys in the North Pacific. At present two buoys are instrumented to measure temperature, depth, and salinity; drift and current are measured by obtaining successive buoy positions. In experiments to date radio direction-finding bearings have been used to track the buoys, and data transmission has been successful up to a range of 900 miles. Consideration is now being given to tracking the buoys and relaying data via satellite. The Navy also has an air-droppable drifting buoy in an early development stage.

Among buoy types being considered for the future are a steel spar buoy, and a light sphere floating like a "beachball" on the ocean surface. Another possibility is a large rugged balloon partially filled with helium which could be equipped with a version of the electronics package under development for constant-level atmospheric balloons; its position on successive satellite passes would yield integrated surface wind data.[5]

III. REMOTE PLATFORMS

Among the most dramatic developments is the ability to collect useful ocean data from a remote vantage point. Earth-orbiting satellites have demonstrated an operational capability to provide global cloud photographs; they have now demonstrated a capability to collect and transmit useful oceanographic data. The satellite is also useful as a data communication relay. Aircraft have been used to test satellite sensors, and have also demonstrated an independent capability to collect oceanographic data.

A. Aircraft Observations

The instrumented aircraft, operated in its own right and as a test bed for satellite instruments, has demonstrated its usefulness as an oceanographic data collection platform.[6] The Coast Guard uses aircraft in ice reconnaissance. The Navy has had considerable experience in flying an instrumented aircraft. The instrumentation has included an infrared device (8- to 13-micron region) to sense sea surface temperatures. Field accuracies of approximately one-half degree Centigrade have been reported. Recent developments include an infrared thermometer that operates outside the

[5] Panel on International Meteorological Cooperation, National Academy of Sciences-National Research Council, *The Feasibility of a Global Observation and Analysis Experiment*, NAS-NRC, Washington, D.C. (1966).

[6] Much of the experience in aircraft observation of the oceans has been conducted by NASA, and other agencies, in support of satellite programs; these activities are described in satellite technology. A useful compendium of aircraft/spacecraft oceanographic data collection experiments is provided in a report prepared for the National Council on Marine Resources and Engineering Development: *The Potential of Observations of the Ocean From Spacecraft*, The General Electric Company Missile and Space Division, December 1967.

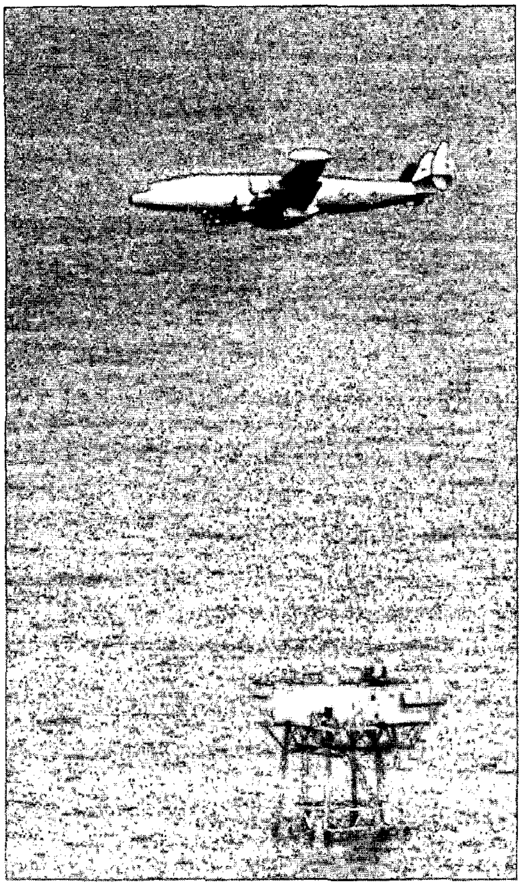

Figure 20. *Navy oceanographic aircraft flying over ARGUS island instrumented tower. (Navy photo)*

water vapor absorption band, and therefore is not subject to any absorption "on the way" to the aircraft. Interest is being shown in the development of an instrument that would measure water vapor in the lower layers of the atmosphere over water by making use of the selective water-vapor absorption of infrared radiation.

The Navy's aircraft has also carried a radar that provides a sea-surface profile, which can be modified for comparison with the usual point spectra. In addition, work is under way on a radar scatterometer, as well as a laser wave gage, to provide higher resolution than existing instrumentation.

Aircraft can also make ocean temperature soundings using an expendable bathythermograph. The buoy transmits a signal to the aircraft, where it is recorded in both analog and digital forms. The sensor is a free-falling thermistor probe, attached to the buoy by a conducting cable.

The Navy's instrumented aircraft has provided a considerable amount of valuable oceanographic data.[7]

NASA aircraft test-flying satellite instruments have also proved the feasibility of collecting oceanographic data by aircraft. Other agencies are proceeding with plans to develop similar capabilities. Satellite instruments tested aboard aircraft may prove useful for operational employment aboard aircraft. We are aware of the considerable aircraft reconnaissance capability of the U.S. Air Force. Consideration should be given to full utilization of this capability for oceanographic measurements by installation of appropriate sensors. Efforts aimed at making airborne oceanographic sensors more rugged and reliable are worthwhile. Further development of the air-dropped expendable BT, with a view to decreasing cost, may make an "aircraft-of-opportunity" program feasible. Energy flux measurements from aircraft would be extremely useful in air-sea interaction research. The role of the aircraft in an observational system, which includes buoys, ships, and satellites, requires further study.

Recommendation:

The oceanographic aircraft role in an operational environmental monitoring system must be reviewed both as an alternative data-collection method and as a means of collecting data of a kind not easily obtainable by other means. Aircraft operated for other missions by various Federal agencies should be instrumented to collect oceanographic data.

B. Satellite Observations

The TIROS, NIMBUS, and ESSA series of satellites have already amply demonstrated the operational capability to provide useful global environmental data (cloud photographs), and other applications are under development. The ATS series, in earth-synchronous orbits have demonstrated the ability to keep major portions of the atmosphere and ocean under constant daytime surveillance.

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[7] Schule, J. J., Jr., and Wilkerson, J. C., Informal Report, *An Oceanographic Aircraft*, Naval Oceanographic Office, Washington, D.C. 20390, January 1967 (Reprinted April 1967) and testimony by Dr. C. Bates before Marine Commission.

To test potential satellite instrumentation, sea surface temperature discontinuities have been detected from aircraft in the visible, infrared, and microwave regions of the spectrum. Infrared instruments have been used to map and measure areas of strong thermal contrast. It also has been possible under night-time, cloud-free conditions to detect areas of sharp temperature contrast, such as currents and upwelling, from NIMBUS Satellite High Resolution Infrared (HRIR) imagery, and several sea-surface temperature analyses have been prepared.[8]

TIROS-M, planned to be in orbit in 1969, will have a two-channel radiometer on board, to observe the atmosphere and ocean in both the infrared band and the visible band. This will provide daytime cloud/non-cloud discrimination, and indicate when the infrared radiometer is sensing the sea surface. A possible future development is the laser altimeter to give precise measurements of the mean sea surface from a satellite. Such data, when used with appropriate equations of motion for the ocean, could yield estimates of major surface current speeds.

Most available sea-state data are visual observations made aboard ships; for wider coverage, sea-state information is inferred from wind data. Possible methods for determining sea-state from orbital altitudes are based on changes in the reflective properties of the ocean surface. Photographs of "sun glitter" or "sun glint" have been made from aircraft and satellites. Another optical technique, to yield a directional distribution of sea slope as well as information about wave fre-

[8] An excellent summary of work in this field to date is provided by Warnecke, G., L. M. McMillin, and L. J. Allison, *Ocean Current and Sea Surface Temperature Observations from Meteorological Satellites*, NASA Technical Report, Goddard Space Flight Center, Greenbelt, Maryland, in press. Infrared instrumentation is reviewed in Goldberg, I. L., 1968: *Meteorological Infrared Instruments for Satellite*, NASA, Goddard Space Flight Center, Greenbelt, Maryland.

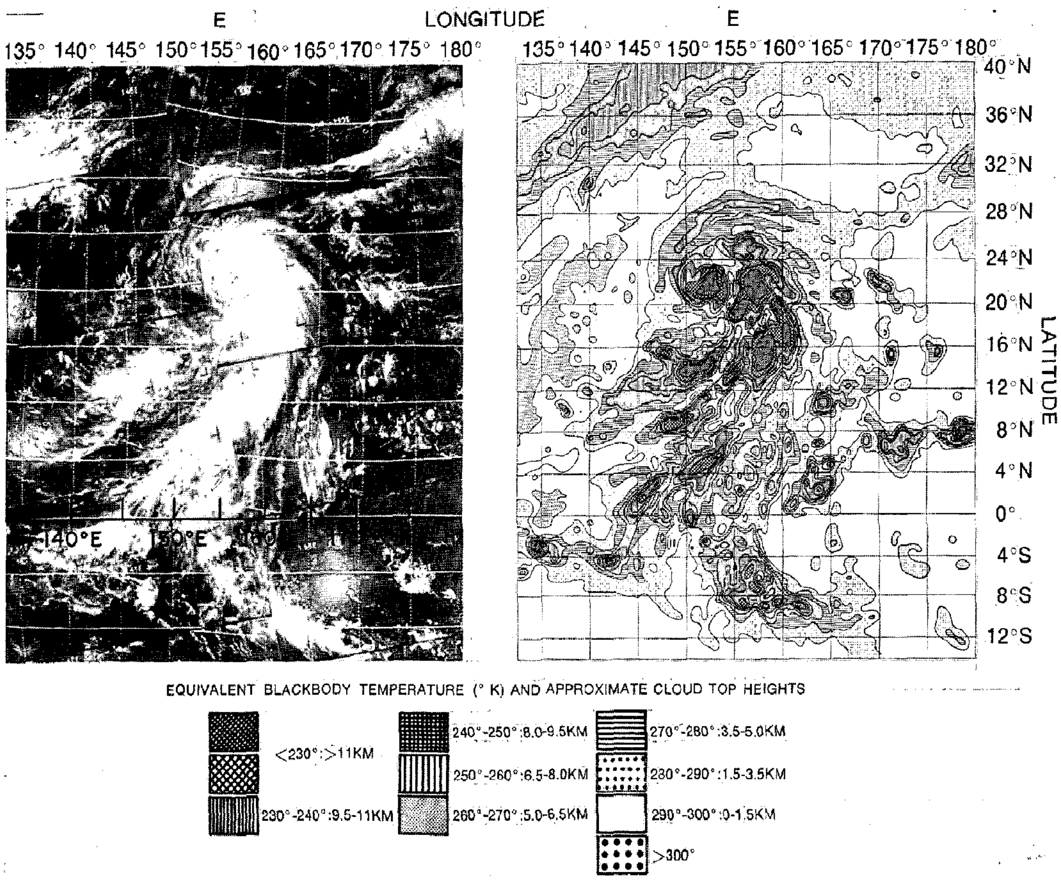

Figure 21. *Comparison of satellite infra-red "picture" (NIMBUS II) and TV photograph (ESSA 3) of typhoon Marie, Nov. 1, 1966. Infra-red data have been converted to cloud-top height estimates (right) to provide analysis of visible cloud structure (left). (NASA photos)*

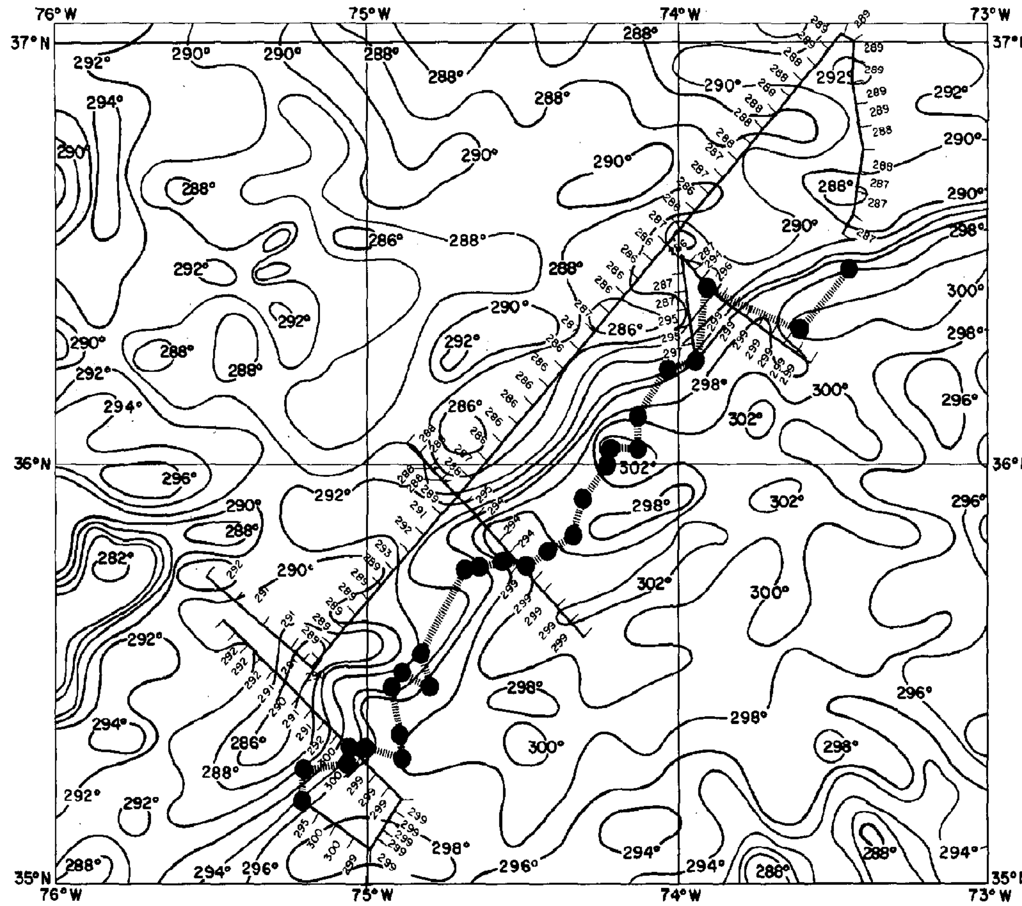

Figure 22. *Comparison of simultaneous NIMBUS II HRIR (orbit 238) and aircraft radiometric night-time measurements (0300 to 0630 GMT) of sea surface temperature near northern Gulf Stream boundary, June 2, 1966. Heavy dots represent Gulf Stream boundary detected in aircraft. Numbers along tracks of aircraft horizontal temperature profiles are average sea surface temperatures between tick marks. (NASA photo)*

quencies, involves the Fourier transform of a sea surface photograph.

The cloud cover constraint on optical techniques has led to the study of passive microwave radiation and radar reflectance for sea-state determination. Both of these measurements can be made with no appreciable attenuation in the presence of storms and clouds. Microwave radiometry data has yielded unique signatures as a function of viewing angle for different surface roughness.

Airborne radar scatterometer data indicate that the return signal yields signatures characteristic of the sea surface energy spectrum, which in turn can be related to the sea-surface winds. If this approach becomes practical, a spacecraft in a near polar orbit would be capable of providing regularly spaced wind speed reports as well as the intermediate sea-surface roughness data over the oceans.[9]

Plans are now being made for a major field experiment during early 1969, involving several aircraft using sensors operating in different frequency bands. In addition to analysis of radar scatterometer data, the Doppler-shift spread due to reflection by the "rough" sea surface will be analyzed. The Ocean Station Ships in the North Atlantic will provide "ground truth."

Television and infrared sea ice data have been regularly obtained from the polar-orbiting meteorological satellites (TIROS, ESSA, NIM-

[9] Pierson, W. J., 1968: *A proposed method for the analysis of surface wind field for the Southern Hemisphere using land stations, ship reports, and spacecraft cloud and radar scatterometer data.* Paper delivered before · 49th Annual Meeting, American Geophysical Union, April 8-11, 1968, Washington, D.C.

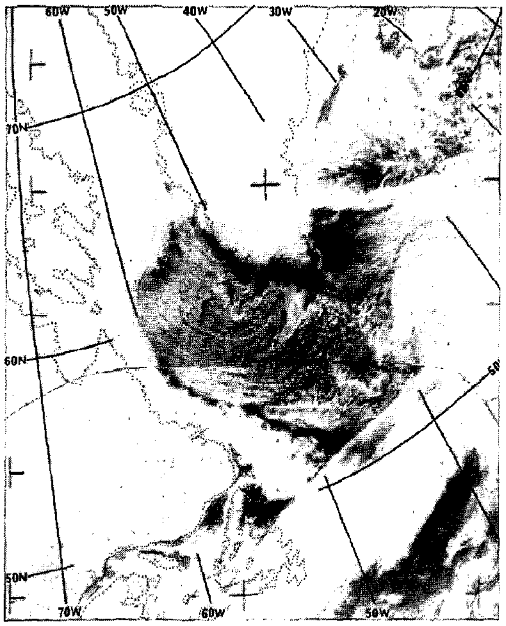

Figure 23. *ESSA 6 satellite photograph of ice and cumulus clouds, Labrador Sea, March 18, 1968. Note solid ice cover over Greenland (top center). (ESSA photo)*

BUS). The International Ice Patrol regularly uses satellite ice data to augment information acquired by ships and aircraft. The U.S. Army Cold Regions Research and Engineering Laboratory, the University of Michigan, and the Naval Oceanographic Office are conducting research in the use of infrared radiometry for sea ice surveys.

These techniques suffer from an inability to see through clouds that are common in the polar and sub-polar areas where ice is present, as well as the limited daylight hours over a portion of the year. As a result, recent studies have turned to the development of other techniques; sidelooking radar and passive microwave imagery. The Coast Guard is investigating the use of microwave imagery for iceberg and sea ice surveys. NASA has reported considerable success in airborne tests of this technique;[10] it may be possible to obtain useful ice-thickness measurements, as well as other related data.

Spectral analysis techniques have been suggested for mapping chlorophyll on the ocean surface for use in forecasting fish abundance.

[10]Catue, C. W. Nordberg, P. Thaddeus, & G. Long. 1967: *Preliminary Results from Aircraft Flight Tests of an Electrically Scanning Microwave Radiometer,* Goddard Space Flight Center, Greenbelt, Maryland, (X-622-67-352) 35 pp.

C. Satellites—Communications

The United States has several programs designed to demonstrate the feasibility of using satellites to locate, interrogate, and relay data from meteorological and oceanographic buoys, stream gauges, drifting balloons, ice islands, and other environmental data platforms. One program is OPLE (Omega Position Locating Equipment), a prototype of which has flown on the synchronous ATS-3 (Application Technology Satellite).

OPLE is capable of interrogating thousands of separate surface units deployed at random, accurately fixing their positions, and recording their data twice daily. This system would provide a means of obtaining data from instrumented buoys as well as sensors on other platforms. Another related program is IRLS (Interrogation, Recording and Location System), planned for flight testing aboard a future polar-orbiting NIMBUS satellite. These techniques must be compared for cost and effectiveness with other, more conventional approaches; such comparisons are in progress.

Recommendation:

The development of satellite-borne oceanographic sensors as well as techniques for the location of, and transmission of data from, other platforms now in progress at NASA should continue. Plans for early use of oceanographic sensors on board operational satellites should be pursued vigorously.

IV. APPRAISAL

Many technical developments are at a stage where they can provide a significant improvement in observing the environment, transmitting and processing the observed data, and retransmitting forecasts. Progress has been noted in the development of new data-collection platforms: satellites and buoys. Developments for remote sensing of the environment from satellites, as well as aircraft, show great potential. New data-processing capabilities, under development primarily for other reasons, also promise an improved capability to process incoming data and provide accelerated forecasting capabilities. Progress in data processing and communications offers the promise of being able to transmit vast quantities of data rapidly and economically.

Recommendation:

The Nation must push forward with a comprehensive and diversified program for the development of new technologies to monitor the global marine environment. Such a program is the key to maintaining adequate surveillance over the total marine environment.

The panel finds that we are at an early stage in the development of a scientific capability for "ocean environmental prediction."

Until the start of World War II, predictions of ocean parameters were essentially limited to those periodic phenomena with well-understood physical mechanisms: tides as well as the motion of easily observed physical singularities such as icebergs. Tidal predictions are still imperfect; improvements are under way to take account of nonlinear effects and transients caused by surface winds and local pressure changes. Iceberg forecasting has improved because of the improved data available. Since the end of World War II (and, in at least one of the cases, stimulated by war-time research) methods have been developed for:[1]

–Surface-wave prediction based on observations and predictions of surface winds

–Warnings of tsunamis produced by earthquakes, detectable at great distances.

Further, at the Navy's Fleet Numerical Weather Central, Monterey, California, computer programs have been developed to provide surface wave predictions. Other forecast parameters describe the temperature structure of the oceans for sound propagation prediction. This program is based on an empirical approach and additional effort is required to establish a firmer scientific basis. Further improvement in wave prediction is tied closely to the prediction of the wind field in the lower layers of the atmosphere, for which more observations of the atmosphere over the oceans are required. Similarly, prediction of the near-surface thermal structure is strongly related to the exchange of heat between atmosphere and ocean.

A wide range of time-dependent phenomena occur in the ocean; there is really no reason why ocean "weather" is not as varied and complex as the weather in the atmosphere.[2] Internal gravity waves, inertial motions associated with the earth's rotation, turbulence, meanders in the Gulf Stream and other currents, and fluctuations in surface temperature over large areas are all examples of time-dependent fluctuations. These phenomena are not yet adequately observed nor their dynamics understood; they therefore cannot be accurately predicted.

[1]Panel on Oceanography, President's Science Advisory Committee, *Effective Use of the Sea*, The White House, Washington, D.C. (June 1966).

[2]*Ibid.*

I. SEA-AIR INTERACTION

Research on the interactions between the atmosphere and the oceans is necessary for progress in ocean and weather forecasting. A successful research program in this field could lead not only to improved weather forecasting, but also, since the upper layer of the ocean and the atmosphere are both part of the same physical system, to the ability to forecast conditions in the upper layer of the ocean.

A theoretical upper limit for predicting the behavior of individual mid-latitude weather details is estimated to be:[3]

about two weeks in winter and somewhat longer in summer; the practical upper limit is now about three or four days. . . . A reasonable estimate for the practical limit in the foreseeable future seems to be about one week, with the possibility that some trends for temperature and precipitation could be predicted for the second week.

For these time intervals the fluxes of energy, momentum, and water vapor to and from the atmosphere, neglected for short-range forecasting, become significant. Because these exchanges occur on scales of motion very much smaller than the scale of any existing or economically-feasible observing system, a major goal of air-sea interaction research is to relate these fluxes to data collected on a much larger scale.

Boundary-flux estimates representative of areas of about 250,000 square kilometers and time intervals of 3 to 12 hours may be required.[4]

[3]Committee on Oceanography, National Academy of Sciences – National Research Council, *Oceanography 1966–Achievements and Opportunities,* NAS-NRC, Washington, D.C. p. 112.

[4]Panel on International Meteorological Cooperation, National Academy of Sciences–National Research Council, *The Feasibility of a Global Observation and Prediction Experiment,* NAS-NRC, Washington, D.C. (1966).

Present estimates indicate that the flux estimates will be required in the absence of any direct measurements of flux. Therefore, it must be possible to estimate the fluxes from standard observed data: air and water temperatures, humidity, wind speed, and sea state.

It should be noted that this scientific limitation has been recognized for some years, and was outlined by the Joint Panel on Air-Sea Interaction of the National Academy of Sciences in 1962.[5] Their report sparked the formation of the Air-Sea Interaction Panel, reporting to the Interagency Committee for Oceanography and the Interdepartmental Committee for the Atmospheric Sciences; the Air-Sea Interaction Panel has served as a forum for exchange of information among the different Federal agencies conducting programs in this area. As a result of the Panel's motivation several Federal agencies are planning a series of major sea-air interaction field experiments coordinated by the Department of Commerce.

The first is planned for the summer of 1969 in the Barbados area.[6] These experiments will provide the opportunity to develop the parameterization called for above, as well as to cross-check the data collected by different sensors.

The need for atmospheric wind data in forecasting ocean waves and swell has been stressed. With an understanding of sea-air interaction, and adequate near-interface data our ability to forecast ocean temperature, depth of mixed layer, and near-surface currents would be enhanced.

The atmosphere and oceans interact on many different scales and modes. The exchange of gases between atmosphere and ocean requires further investigation; this may yield the key to the final disposition of carbon dioxide dispersed into the atmosphere. The sea is the source of salt particles, which play an important role as nuclei in the formation of precipitation, as well as of the water itself.

At the other end of the spectrum the atmosphere-ocean interaction plays a key role in the global redistribution of the energy received from the sun. Although still largely empirical, long-range weather forecasting techniques require extensive ocean surface temperature data. Anomalies in sea surface temperature have been found to be closely associated with major shifts in weather. Some success has been achieved recently by computer-prepared forecasts of monthly and seasonal temperatures in the atmosphere-ocean-continent system, which included ocean surface temperatures as a forecast parameter. The model has also been used to forecast monthly departures from normal of the ocean surface temperature; this model requires extensive atmospheric data as input.[7] Additional research is in progress, relating large-scale atmospheric and sea-surface temperature anomalies in the Pacific, using data provided by satellite infrared sea-surface observations;[8] such interactions have been noted by other investigators.[9] Numerical calculations have been conducted, which include the effect of the sea-surface temperature field on the large-scale atmospheric circulations.[10]

Progress is also being made in the development of computer models which attempt to unify the atmosphere and the ocean; some success has been achieved in predicting the gross features of both the atmosphere and the oceans.[11]

II. SCALES OF MOTION

As additional data describing both near-surface and deep ocean currents become available, we find that the observed current may actually have only a weak relation to the mean currents. To study

[5] Joint Panel on Air-Sea Interaction, National Academy of Sciences–National Research Council, *Interaction Between the Atmosphere and the Oceans,* NAS-NRC, Washington, D.C. (1962).

[6] *Plan for a Major Field Experiment in Support of the Federal Air-Sea Interaction Research Program,* U.S. Department of Commerce, ESSA, Institute for Oceanography, March 1967, Washington, D.C.

[7] Adem, J., On the physical basis for the numerical prediction of monthly and seasonal temperatures in the troposhere-ocean-continent system, *Monthly Weather Review,* 92(3). pp. 91-104, 1964; Experiments Aiming at Monthly and Seasonal Numerical Weather Prediction, *Monthly Weather Review,* 93(8) pp. 495-503, 1965; Numerical prediction of mean monthly ocean temperature, Unpublished manuscript.

[8] Personal communication from L. Allison, NASA.

[9] Namias, J., 1959. Recent Seasonal Interaction between Northern Pacific Waters and the Overlying Atmospheric Circulation, *Journal of Geophysical Research, Vol. 64, pp. 631-646.*

[10] Mintz, Y., 1965, Very Long-Term Global Integration of the Primitive Equations of Atmospheric Motion, Technical Note No. 66, WMO-IUGG Symposium on Research and Development Aspects of Long-Range Forecasting, Boulder, Colorado, 1964.

[11] Manabe, S., and K. Bryan, Numerical Results From a Joint Ocean-Atmosphere General Calculation Model, paper presented at 14th General Assembly, IUGG, Lucerne, September-October 1967.

seasonal and other variations the oceanographer faces problems in the geographical and time spacing of the observations; this difficulty is a manifestation of our ignorance of the spectrum of variations in the sea's motions. The National Academy of Sciences Committee on Oceanography has stated:[12]

The classical oceanographic cruise is inadequate to sample the high-frequency and small-scale phenomena, and oceanographic expeditions are generally not long enough or extensive enough to sample the low-frequency or large-dimension phenomena.

Data provided by moored buoys have improved our understanding of the time distribution of horizontal motion, but little in spatial variations. Transient inertial currents account for a large fraction of the kinetic energy. For periods shorter than 12 hours (corresponding to horizontal dimensions of 10 kilometers or less), the energy density of velocity fluctuations decreases with frequency. Vertical scales are not known.

Considerable statistical similarity of the velocity fluctuations is found in this frequency range at all depths and locations sampled. The energy content at frequencies below one cycle per day tends to increase with decreasing frequency, but the knowledge of temporal and spatial distribution is scanty. The requirement for long-term records from many sampling points has made the larger-scale low-frequency portion of the spectrum relatively inaccessible.[13]

Data collected by research and survey ships along "standard sections" can supplement arrays of fixed current meters. NASCO has indicated that standard sections can be designed with the aid of measurements from anchored instruments and periodic series of ship observations.[14] The Coast Guard has established standard oceanographic sections in the North Atlantic and North Pacific Oceans to provide information on the seasonal and longer-term variations in the flow of the major current systems. Data is collected by Coast Guard ships en route to ocean stations, as well as by Coast Guard oceanographic vessels; additional data is provided by Canada. These measurements are usually made on a seasonal basis–four times per year. Recently, the Pacific sections have been sampled almost monthly. The data collected include temperature and salinity down to 1,500 meters, or the bottom, whichever is lesser, with intervals selected on the basis of the dynamic gradient.

III. DYNAMICS OF OCEAN CURRENTS

The general positions of the ocean's major current systems have been fairly well established for more than 50 years. As more detailed observations are made of the current systems, however, more is learned about their non-uniformity. Recent observations have shown, for example, a highly complex structure for the pattern of ocean currents near the Equator in all oceans. The general driving force of the ocean's current systems are the more-or-less permanent atmospheric wind systems, combined with the earth's rotation. This response, and the relationship of the fluctuations of the ocean currents to the turbulent character of the atmosphere's wind, are poorly understood. Ocean currents are roughly the equivalent of atmospheric-wind systems, on an ocean-wide scale, with a degree of persistence, month after month, not characteristic of the corresponding atmospheric circulation. The general direction of the major current systems' flow is easily predicted. The meridional advection of heat by persistent ocean currents is a major influence on global climate.

Additional data is required to define the detailed structure of the current systems; this must be coupled with basic research into the atmospheric wind-ocean current energy exchange as well as studies of bottom effects on ocean currents. Research efforts have achieved computer simulations of the major features of the atmosphere's general circulation and the ocean's broad current features.

IV. BIOLOGICAL PREDICTION

Man's increasing dependence on food resources from the sea and his growing capacity to modify

[12]Committee on Oceanography, National Academy of Sciences–National Research Council, *Oceanography 1966–Achievements and Opportunities*, NAS-NRC, Washington, D.C. (1967).

[13]*Ibid.*

[14]*Ibid.*

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the environment lend urgency to the requirement for improved biological prediction. Capabilities for biological prediction now are relatively primitive and limited to a few commercially significant species. To improve the efficiency of fishery operations accurate forecasts of the abundance and distribution of major marine populations must be made. Rates of production and mortality, interactions with other species and with the environment must be predictable, not only from the point of view of developing new food sources and gauging the effects of existing fisheries, but also to evaluate the effects of man's modification of the environment.

Recommendation:

Intensive research efforts should be mounted to provide the necessary understanding of oceanic processes in:

–Sea-air interaction

–Scales of motion

–Dynamics of ocean currents

–Biological-physical environmental relationships

Such understanding is essential for development of a wide range of environmental predictions.

I. BASIC AUTHORITIES

The Navy, under its broad authorities, maintains an extensive oceanographic and meteorological data collection, processing, and dissemination system. SECNAVINST 5430.70 of Aug. 19, 1966 established the Office of the Oceanographer of the Navy, to exercise centralized authority, direction, and control of the Naval Oceanographic Program. The program encompasses science, technology, engineering, and operations, including essential personnel and facilities to explore and lay the basis for exploration of the ocean and its boundaries for naval applications to enhance security and support other National objectives. The Department of Defense service concept is to meet military requirements by providing forecasts and analyses tailored for the individual military user or operation; the Navy provides oceanographic support to U.S. and NATO forces worldwide.

The Coast Guard (Department of Transportation) under 14 USC §90 operates and maintains floating ocean stations for search and rescue, communication, and meteorological services in such ocean areas as are regularly traversed by U.S. aircraft. The section states that the:

Coast Guard shall conduct such oceanographic research, use such equipment or instruments, and collect and analyze such oceanographic data, in cooperation with other agencies of the Government, or not, as may be in the national interest.

Under 46 USC §738, the Coast Guard is charged with the responsibility for "patrol and service for the study of ice endangering the shipping tracks of the North Atlantic Ocean."

The U.S. Weather Bureau was established in 1890 and operates under the authority of 15 USC §311, which states, in part, that:

The Chief of the Weather Bureau shall have charge of the forecasting of the weather, the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce, and navigation, the gauging and the reporting of rivers, the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation.

The Environmental Science Services Administration, established by Reorganization Plan No. 2 of 1965, combined the Weather Bureau, the Coast and Geodetic Survey, and the National Bureau of Standards' Central Radio Propagation Laboratory. ESSA's primary mission includes the description and prediction of the physical environment. In transmitting the Plan, President Johnson spoke of ESSA as providing:

a single national focus for our efforts to describe, understand, and predict the state of the oceans, the state of the lower and upper atmosphere, and the size and shape of the earth.

ESSA has specific authority for comprehensive programs with respect to meteorology and oceanography. Various provisions require collaboration in the collection and dissemination of weather data, and the conduct of meteorological research, between ESSA and such other agencies as the Department of Defense and the Department of Transportation. Included is authority for ESSA to act as Federal coordinator for meteorological requirements.

The Secretary of the Interior is authorized to carry out extensive oceanographic, biological, technological, statistical, and economic programs to ensure rational use of marine resources. The role of environmental monitoring in the Departmental programs is to provide those data needed to support development of marine food, recreational, mineral, and water resources.

Under the Fish and Wildlife Act of 1956, as amended, the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife are authorized to take such steps as may be required for the development, advancement, conservation, and protection of fishery resources. To carry out this policy the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife collect, analyze and disseminate those environmental data needed for predictions of abundance and distribution of fishery resources to ensure proper management and rational development.

To fulfill responsibilities under the Federal Water Pollution Control Act, as amended, the Federal Water Pollution Control Administration is authorized to collect and disseminate data on chemical, physical, and biological water quality and other information insofar as such data or other information relate to water pollution and the prevention and control thereof. The Geological Survey monitors geologic processes in the marine environment; it is authorized to determine the source, quantity, quality, distribution, movement, and availability of both surface and ground water, including the estuarine and other coastal waters, and fresh water sources beneath the coastal zone. The Survey is further authorized under Bureau of the Budget Circular A-67 to operate and maintain a National system for water data coordination, which includes data from estuaries. The Geological Survey does much of the data collection itself, mainly through cooperative investigations with States and other local agencies.

II. INTERAGENCY COORDINATION

Management, planning, and coordination of various environmental monitoring and prediction programs is vested by statute or by executive agreement in various agencies and in the Executive Office of the President, including the Bureau of the Budget, the Office of Science and Technology, the Federal Council for Science and Technology, the Marine Council, and the Water Resources Council. Particular departments are given coordinating responsibilities over certain of the marine programs, such as the Department of Interior for fisheries and water resources, and the Department of Commerce for meteorology.

It is clear that the elements comprising the National marine environmental prediction service now reside in several agencies of the Federal Government. Other agencies are involved in related atmospheric monitoring and prediction activities. The scattering of responsibilities through many Federal agencies has caused funding and management difficulties.

The complexity of the problem is illustrated by the ocean-station-vessel program. This international activity is under the jurisdiction of the International Civil Aviation Organization. The ships serve as communications relays in support of commercial aviation, as well as performing search and rescue missions. Those ocean stations that are the responsibility of the United States are manned by Coast Guard ships. As a major mission, these ships also collect meteorological and oceanographic data. The Department of Defense funds environmental observations taken aboard the ships by transferring funds to the Department of Commerce to provide observing teams for the ships. Additional data are collected by Coast Guard personnel.

Special arrangements exist for the collection of meteorological data in support of aviation interests, between the Federal Aviation Administration and ESSA. The Coast Guard transmits many ESSA forecasts and warnings to marine interests.

Since the passage of the Marine Resources Act, the National Council on Marine Resources and Engineering Development has provided a focus for coordination of the National oceanographic program. It has been able to establish clearly defined agency responsibilities for some major programs and insist on program coordination although these decisions may not have been optimum or popular with all agencies.

The Council has established the Interagency Committee on Ocean Exploration and Environmental Services charged with developing a Federal Plan for Marine Environmental Prediction. The Committee has considered the problem of coordinating the activities of the several agencies in executing the plan, but has limited its consideration to means for coordinating the activities of several independent agencies.

The Committee has stated that a program planning steering group and project coordination mechanism are required; it is not in a position to propose any changes in statutory responsibilities. It is the panel's opinion that devices of this character will not be completely effective in developing an efficient National Environmental Monitoring and Prediction System.

Several efforts have been made to provide interagency coordination in meteorology. The Department of Commerce established the Office of the Federal Coordinator for Meteorological Services and Applied Meteorological Research in response to Bureau of the Budget Circular A-62 to provide a focus for review and coordination of meteorological service and supporting research programs. As part of its mission this office has recently completed the preparation of a Federal plan for Marine Meteorology coordinating the activities of all participating Federal agencies.

The Office of the Federal Coordinator has the responsibility for the coordination of meteorological programs only. It has no directive authority over governmental agencies. It has been able to effect a policy of sharing facilities and, in some cases, has been able to forestall the establishment of duplicate facilities.

In addition, the Interdepartmental Committee for the Atmospheric Sciences coordinates "basic" research in meteorology, reporting to the Federal Council for Science and Technology.

III. ORGANIZATIONAL OPTIONS[1]

A viable marine monitoring and prediction system depends both scientifically and technologically on close integration with the corresponding meteorological system. Operational costs can be significantly reduced when common platforms are used for observing both elements of the environment. The same argument applies to the use of communications links, data processing, and dissemination systems. Therefore, the marine environmental monitoring and prediction system for both ocean and atmosphere should be planned and operated to the extent possible as a single system.

Of the organizational options identified by the panel for the expanded environmental monitoring and prediction program, the first two would continue present agency responsibilities, (1) including appropriate interagency coordination or (2) assigning coordination responsibility to a lead agency.

Either of these options would continue the present fragmentation of effort with attendant management and funding difficulties. Neither a coordinating committee nor the lead agency concept has proved fully effective. Experience to date has indicated that the coordinating committees serve as forums for the discussion of the programs of the individual agencies, which each agency funds. Agreements reached in committee, assigning individual agency responsibilities, can founder due to inadequate funding in any of the participating agencies.

[1]The various options are intended to provide for the conduct of operational activities and supporting research, but not for basic research.

The principal value of interagency coordinating committees in the past has been the exchange of information describing agency programs. Such committees can only have an indirect effect on agency budgets, and thus they tend to be ineffective in "moving" an agreed-upon-multi-agency program. In some cases, where it was advantageous to all agencies involved, it has been possible to eliminate duplication. This has been particularly true when the duplication was in regard to the planned establishment of new facilities.

The lead agency concept has not proved effective in advancing National program objectives. The lead agency has tended to be the agency with the responsibility, but often without the budget to carry out its responsibility. Recent experience, supported by testimony of witnesses before the panel, indicates that the citation of the lead agency responsibility as a funding argument has not been very successful.

(3) Conduct of the entire program by the Department of Defense is an option which might result in civil requirements being placed after military requirements. The military chain-of-command tends to operate in such a fashion that military commanders must be satisfied; this may be expected to cause delays or priority reductions in purely civil aspects of the program when conflicts occur for application of relatively scarce resources.

Military security considerations may tend to hinder development of the civil portion of the program. It is usually easier to classify an entire program than to carefully examine it to determine the activities that can be unclassified (or declassified) and those that are genuinely critical.

As a result, orderly development of the environmental monitoring and prediction program by the full participation of the scientific community may be restricted if some aspect of the program causes significant portions to be over-classified.

In some countries the military has the responsibility for all national environmental programs (Italy is an example); in such cases civil requirements do not usually receive required priority, and representation at international functions is hampered. In other countries (England and Canada are examples) a civil agency provides environmental services to the defense establishment.

The scale of the Defense Department budget would probably make funding of the environmental monitoring and prediction program considerably easier than it is today, if the program were entirely in the Defense Department; it is the question of whether these funds would be allocated for the best over-all interests of the Nation that influences the panel's opinion with regard to this option.

(4) Present DOD programs could be continued and the civil program in several Federal agencies expanded, possibly including some not now active in the program. This option might increase the number of civil agencies in the total program and thus increase its fragmentation with an accompanying lack of economy. With increased funds in this program the present or any alternate interagency coordination scheme would be less efficient than such coordination is today.

(5) The military-related program in the Defense Department could be retained with consolidation of all civil activities in one Federal agency, except for the Coast Guard's logistic support services, or

(6) The logistic support agency could be placed within the major civil agency.

These options would continue the separate civil and military systems, but could achieve significant economies by concentrating the civil program in one agency. Coordination and lead agency problems would be significantly eased, and the number of committee meetings required to coordinate the National program would be significantly reduced. Program management and system design efforts would be strengthened if the civil program were unified in one agency. At present there is, for example, no clear agency responsibility for evaluating the total system in terms of the trade-off between satellite and buoy data collection systems.

In one case (5) the marine logistic capability of the Coast Guard would be called on by the responsible operating agency; in another (6) these activities would be absorbed into the operating agency. In these options, the civil agency may operate a facility for joint civil/military use, such as the National Environmental Satellite System. The establishment of unified Federal positions in regard to international meteorological and oceanographic prediction activities, now a relatively difficult problem requiring coordination and review by many agencies, would be greatly facilitated if the responsibilities for the civil programs were centered in a single agency.

(7) All programs, including those in support of military operations, could be consolidated in one civil agency. This option would necessitate the establishment of a means to assure the Defense Department that military requirements could be adequately met by the civil agency.

The civil agency would have to gear its operations to provide rapid response to military requirements. In general, experience is such that military requirements and, in particular, the required quick-response capability, necessitate a system that is under military control.

The panel favors option (5) or (6) but an explanation is required to indicate, in detail, the nature of the responsibility that would be assigned to the new or modified existing Federal agency, as well as that to be retained in the Department of Defense. It is not intended that DOD would maintain facilities duplicating those of a civil agency in all respects. As now established in meteorology the collection of basic oceanographic data would be a shared responsibility; in effect all observed data would be pooled and available both to the responsible civil agency and the DOD.

Some environmental service requirements are common to both civil and military users. The National upper-air sounding network, operated principally by ESSA, is an example of a civil program that satisfies both military and civil requirements. This program provides upper-air meteorological data to the Nation's basic meteorological service (civil) as well as the corresponding military programs. As additional planned services to civil users are implemented, many of the products of the civil agency will meet such common requirements. This will free some military resources to concentrate on requirements unique to military operations.

Until services to civil users have been expanded, products designed for military users which are appropriate and can be made available will be used to meet requirements of civil users. This use of military products will be "ad interim" except in those cases where common requirements can be met most effectively and economically by their continued use.

The basic data collection network would be a joint operation in this sense, although military and civil data collection stations would be operated. Thus data collected aboard naval vessels would be available to the civil agencies, and data collected aboard merchant vessels would be available to the Navy; this is essentially how the present system works although it is more fragmented. In meteorology, basic data are collected by the Department of Transportation, the Department of Defense, Department of Commerce, and certain properly certified private groups.

A single civil communication system would be established for the collection of data by the civil agency. For purposes of reduced vulnerability and military security some portions of the network would exist in parallel with DOD.

For data processing and forecasting it is essential that the civil agency and the DOD maintain separate facilities. As the scientific basis for environmental prediction is strengthened it will be possible to rely on high-speed electronic computers for more of the supporting operations: for example, data checking and communication buffers. With increasing automation of the forecasting process the system becomes more reliant on such automatic equipment, and as a corollary, more vulnerable. To provide back-up and increased reliability it is essential to the National interest that such major environmental data processing centers operate in parallel.

The military and civil services must tailor their forecasts for particular classes of users, and it is expected that both the civil agency and the DOD would maintain relatively independent forecast dissemination activities. As in meteorology today, the civil agency would provide broad forecasts for the general public, industry, and other Federal agencies including the military; in cases where these must be refined to meet the needs of special interests the refinement would be the responsibility of the private sector. In some cases other Federal agencies would refine the basic forecasts to serve special classes of operations. DOD would continue to provide specialized environmental services to meet military requirements.

In addition to the provision of broad services to the private sector, and special military requirements, there are many environmental services required by public agencies at all levels of Government.

Special consideration must be given to the interface between a local small-scale environmental activity and large-scale global services. One example of special interest concerns the myriad of activities in the Nation's estuaries. Many agencies operating in the public interest are conducting monitoring programs that include measurements of physical, as well as chemical and biological parameters. Such measurements are conducted with specific reference to controlling pollution levels and examining the effects of such pollution on marine life, and would normally be the responsibility of an agency charged with a mission related to estuarine pollution control and abatement.

The data collected in such programs will be on a scale considerably smaller, and often on a greater frequency, than those required to support the major environmental prediction services considered in this report. The relatively small-scale behavior of an estuary, however, is strongly influenced by the larger scale motions of the oceans and the atmosphere. For this reason, the local agencies conducting estuarine-oriented programs must be assured rapid availability of appropriate data collected by the larger scale network.

The data collected and forecasts issued by the NEMPS would serve as major inputs to the more detailed forecasts and resulting regulatory actions of the estuarine agencies. On the other hand, the special mission-oriented data collected, typically on a relatively fine mesh, within the estuary would not be required for the operation of the NEMPS. In some cases a single data collection station might serve both a local estuary activity as well as the broader mission of the NEMPS.

In the atmosphere an essentially analogous situation occurs in the monitoring and control of pollution. As a result of recent legislation, it is intended that Regional Air Quality Commissions will be established, which may include more than one local political subdivision. In order to effectively protect the public, a regional air pollution control agency will require local measurements of the concentrations of major pollutants as well as appropriate meteorological data. The dispersion of these pollutants within the region is a function of these parameters as well as of measurements that describe the "large-scale" meteorological situation.

The regional pollution control agency will therefore require data describing the relatively large-scale meteorological situation in addition to meteorological and air pollution concentration data on a much finer grid within the control region. In many cases, physical parameters measured for the purpose of serving the National forecasting system will also be useful to the local control authority. Generally, the regional control agency therefore will require the data describing the large-scale atmospheric behavior in addition to its own local data, while the national meteorological forecasting system will not require the fine scale data collected within the control region.

Biological data requirements are both qualitatively and quantitatively different than either physical or chemical measurements. Biological prediction programs probably will be best accomplished within the individual agency; close coordination should be maintained with NEMPS to assure compatibility and effective use of systems for sensing, communication, and data processing. In many cases sharing of data-collection platforms can be achieved.

Recommendation:

Activities in the National Environmental Monitoring and Prediction System serving common civil and military interests should be consolidated in one Federal agency; specialized military programs should be retained in the Department of Defense. Civil and military environmental monitoring and prediction systems should develop within the following guidelines:

–A common, shared data acquisition network

–A common, shared communications network, except where military security requires separate systems

–Independent, parallel data processing and forecasting facilities

–Independent, specialized data and forecast dissemination sub-systems.

IV. OTHER ORGANIZATIONAL CONSIDERATIONS

A. National Oceanographic Data Center

The National Oceanographic Data Center now archives marine environmental data, providing such data in various forms to Federal agencies and other research groups under appropriate reimbursable funding arrangements. The Center was established in 1960 by Interagency Agreement involving the Navy, Coast and Geodetic Survey, Bureau of Commercial Fisheries, National Science Foundation, Atomic Energy Commission, and the Weather Bureau. These agencies agreed to jointly fund the NODC, with actual operation the responsibility of the Navy. The basic operating funds for the NODC are now provided by: National Science Foundation, Atomic Energy Commission, Coast Guard (DOT), Coastal Engineering Research Center (Army), Bureau of Commercial Fisheries, Geological Survey, and Federal Water Pollution Control Administration (Interior), Department of Health, Education and Welfare, ESSA, and the Navy.

The funding arrangements have limited the modernization of NODC's physical plant, and severely hampered expansion generally. In particular, the application of modern electronic computers to oceanographic data processing has not proceeded at a satisfactory pace. Indeed, for such data processing as NODC does perform it must find "time" on one of several computer systems operated by other agencies.

For these reasons, we feel that NODC should be part of a major Federal agency. A considerable amount of surface oceanographic data is now archived by ESSA's National Weather Records Center in addition to meteorological and other geophysical data. All physical environmental data should be available through a common source after a suitable standard request. Further, vast quantities of data for the proposed atmospheric/oceanographic data bank will be provided by the normal operations of the NEMPS.

Recommendation:

A coordinated system of oceanographic and other environmental data centers should be established. The NODC should be transferred to the civil agency responsible for the National Environmental Monitoring and Prediction System. This agency should be given the responsibility for its funding and management.

B. Satellite Data Collection

As new oceanographic sensors become available for satellite operation, questions arise as to their mode of employment.

The relationship of ESSA's weather satellite program to NASA provides an example of a successful working arrangement. NASA now has the responsibility for the development of new sensors to be carried aboard meteorological satellites; the performance specifications are prepared by ESSA. NASA launches the satellite and places it in the prescribed orbit. When certified as fully operational, the satellite is turned over to ESSA which maintains operational control, receiving data through its own read-out stations, and transmits appropriate raw and analyzed satellite data over standard meteorological communications circuits. These arrangements have yielded excellent system performance.

In regard to new oceanographic sensors the question arises as to whether they should be flown aboard specific "oceanographic" satellites or, where feasible, share a platform. In many cases, it is desirable to obtain physical oceanographic and meteorological data from the same area simultaneously; for this reason it would be well to fly ocean and atmosphere sensors aboard the same satellite. NASA considers the development of ocean sensors as part of its earth resources program; thus future developments may lead to ocean sensors being coupled with sensors developed to map specific resources. Conceptually, satellite oceanographic sensor development should be considered part of the environmental sciences effort. Wherever feasible, these sensors, if not requiring a separate satellite for engineering reasons, should be coupled with atmosphere sensors.

Recommendation:

The agency responsible for NEMPS should adopt arrangements with NASA for satellite oceanographic sensor development and operation similar to those which have worked effectively in the National weather satellite program.

I. INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

As a result of the impetus of the International Geophysical Year in promoting joint scientific attack on the ocean's problems, a resolution was introduced in 1958 at the Tenth General Conference of UNESCO which led to a Preparatory Meeting of the Intergovernmental Conference itself in Copenhagen in July 1960. Following the recommendations made at these meetings, the Eleventh General Conference of UNESCO in 1960 established a UNESCO Office of Oceanography and the Intergovernmental Oceanographic Commission. The Commission held its First Session in Paris in 1961, and subsequent sessions in 1962, 1964, 1965, and 1967. General Sessions are usually held every two years, at which time the Commission's work is reviewed, and general policy for the next two years is established. Sessions also elect the officers and select the Bureau and Consultative Council (BCC) which meets at least those years that the IOC does not meet and other times as required. The BCC carries on executive functions of the IOC.

The purpose of the Commission is "to promote scientific investigation with a view to learning more about the nature and resources of the oceans, through the concerted action of its members." The Commission attempts to stimulate national interest in oceanography and oceanographic research, both national and cooperative. The Commission fosters international cooperation, and is charged with reviewing the results of scientific investigations, defining the basic problems requiring international cooperation, and recommending the nature, form, and methods of oceanographic data exchange.

Commission membership is open to all members of UNESCO, the UN, or other UN agencies, that are willing to participate in oceanographic programs that require concerted action. Its present membership is 58 countries. The U.S. delegation to IOC meetings usually includes representatives of several governmental agencies as well as non-government scientists; the changing character of this representation is a continuing problem. U.S. positions are generally developed by the agency members of PIPICO (Panel on International Programs and International Cooperative Organizations), which reports to the CIPME (Committee on International Policy in the Marine Environment, an interagency sub-cabinet level committee); both committees operate under the Department of State. They serve as advisory bodies to the Department of State, which establishes the final U.S. positions. No single Federal agency has the responsibility for leading in the establishment of U.S. positions, as is customary for many other international organizations such as the Department of Health, Education and Welfare with regard to the International Health Organization and the Department of Labor with regard to the International Labor Organization. This has caused difficulties from time to time in establishing U.S. positions, as well as in general participation in IOC affairs.

The Commission Secretariat is provided by the UNESCO Office of Oceanography. IOC has no funds of its own; UNESCO provides most services, although other agencies or governments may contribute. International cooperative programs are coordinated by International Coordination Groups; the chairman of each group is the International Coordinator for the expedition. Other IOC projects, such as coordination of international oceanographic data exchange and study of various scientific problems, are undertaken by working groups.

The commission receives advisory services from two bodies designated at its Second Session:

–The Scientific Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU is a non-governmental body) advises IOC on broad scientific aspects of oceanography.

–The Advisory Committee on Marine Resources Research (ACMRR) of the Food and Agriculture Organization of the UN advises IOC on the fishery aspects of oceanography.

The IOC has sponsored several major international cooperative expeditions, such as the

International Indian Ocean Expedition. In addition, the working groups have engaged in a variety of activities directed toward specific scientific problems.

At its meeting in October 1967 the IOC moved to engage in operational activities and established the IGOSS (Integrated Global Ocean Station System) Working Committee, and a number of associated panels and working groups. The first meeting of the IGOSS Working Committee was held in April 1968; the Committee prepared a number of findings.[1] The purpose of IGOSS is to provide more extensive and timely information on, and prediction of, the state of the oceans; it is intended to be a global oceanic system, consisting of national facilities and services to be provided largely by the participating countries. The Committee recommended that IGOSS be planned and operated in close coordination with the World Weather Program.

Tentative plans call for the IGOSS to include the following components:

–An observational network comprising all types of ocean data stations and observational techniques:
automatic telemetering buoys
coastal stations and research vessels
fixed ocean stations and mobile ships
fixed off-shore platforms
observational satellites
other new means that may be developed.

–A communication service for data transmission.

–Centers for collection, processing, retrieval, and dissemination of data.

The Working Committee adopted guidelines for the plan and implementation program of IGOSS. The implementation of IGOSS is planned in two phases:

–A program using existing technology to be developed for consideration and approval by the appropriate IOC and WMO bodies in 1969–to be correlated with World Weather Program implementation plan.

–A program using advanced technology, to be developed for consideration and approval at the IOC and WMO Congress meetings in 1971.

Various working groups and panels of experts have been established to examine specific aspects of this program: Requirements, Telecommunications, Data Exchange, and Legal Aspects.

II. WORLD METEOROLOGICAL ORGANIZATION

To facilitate international cooperation in meteorology and organize the necessary mechanisms for exchange of weather data, the International Meteorological Organization was established in 1873 by the directors of national weather services. This was replaced in 1951 by the World Meteorological Organization, a specialized agency of the UN, which now has 130 member nations.

The WMO is organized in several commissions, including the Commission on Synoptic Meteorology and the Commission on Maritime Meteorology. The WMO has set the standards followed in all international meteorological data collection and transmission. Generally, the WMO has established the practices and procedures for weather reporting at sea, and the provision of meteorological service for shipping. Of special interest is the program for the collection of meteorological data by merchant ships at sea, which has evolved into its present form over about a 50-year period. All aspects of this program are coordinated and organized by the WMO:[2]

–Standards have been established for instrument calibration. Instruments are usually furnished by national weather services, and the WMO publishes a worldwide list of instrument repair facilities.

–Coastal radio stations are designated throughout the world for the reception of weather reports from ships at sea.

–WMO has established standard transmission procedures.

The cost of transmission to the United States is repaid to the ship; and transmission from coastal station to the National Meteorological Center is

[1]UNESCO, IOC, Recommendations of the First Meeting of the IOC Working Committee for an Integrated Global Ocean Station System (IGOSS)–UNESCO, Paris, April 2-5, 1968 (Annex II).

[2]WMO Publication 9. T.P. 4–Vol. D. WMO, Geneva.

covered by ESSA. The United States receives about 900 such worldwide reports daily relayed from "collection points" to which they have been radioed by the ships. The WMO is now seeking to expand this program, including participation by fishing fleets not now in the program.

The WMO meets in "Congress" every four years, and maintains a continuing Secretariat in Geneva. Operational activities are primarily coordinated by six Regional Associations (R.A.), which meet every four years, usually not in the same years as Congress (the United States is a member of two R.A.). Between sessions of the Congress the work of the WMO is furthered by annual meetings of the executive committee.

The U.S. delegation to the WMO Congress is chaired by the "permanent representative to the WMO," normally designated by the Secretary of State as the Administrator, ESSA. U.S. positions are recommended to the Secretary of State by the permanent representative, in consultation with all agencies conducting meteorological operations, including the Defense Department; the Secretary of State then reaches final positions, and makes them known to the permanent representative. In addition, the WMO maintains several Commissions, organized by disciplinary areas, such as the Commission on Maritime Meteorology. The WMO seeks technical expertise by forming suitable Working Groups and Panels of Experts; membership in these groups is usually open to any interested nation.

The WMO is also taking a major role in the establishment of the World Weather Program. This program originated in two UN resolutions, one adopted in 1961, and the second a year later; the UN recommended that all member states and appropriate international agencies seek to improve weather forecasting and to further scientific research on the atmosphere. The resolutions called upon the WMO, in collaboration with UNESCO and ICSU, to develop a program to help meet these goals.

Out of the ensuing discussions have come the proposals for what is now identified as the World Weather Program. This program is two-fold:

–World Weather Watch–a new international system for observing the atmosphere over the entire globe, and transmitting, processing, and analyzing the world-wide weather data.

–A comprehensive, long-term research program on global weather systems, including the associated data-collection effort, and on the atmosphere-ocean and atmosphere-land interactions.

The research program is intended to yield an improved understanding of the atmosphere's general circulation. The World Weather Watch would exploit new developments in space technology, instrumentation, data processing, and communications, as well as traditional techniques. Both portions of the World Weather Program are under active planning, not only in the WMO, but also in ICSU for the Global Atmospheric Research Program, including the Air-Sea Interaction Research Program.

Under the existing international weather system, the world exchange of data, analyses, and forecasts cover many parts of the globe, but there are several deficiencies in the system: in observing the atmosphere, in data processing, and in communications.

The first phase of the World Weather Program is intended to remedy the current deficiencies. The second phase includes the introduction of new technology, major research efforts in the general circulation of the atmosphere, and in air-sea interaction. The United States is actively participating in all aspects of this program. Agreement on steps to be taken by member nations as their part in implementing the World Weather Program is reached in the WMO; each nation is responsible for funding those activities agreed upon. U.S. positions are coordinated by the State Department, and represent the consensus of agency positions reached in meetings of the Federal Committee on Meteorological Services and Supporting Research.

In its review of Federal agency programs, the panel members were briefed on this nation's plans to participate, on a cooperative basis, with many other nations in the World Weather Program. The President has endorsed this program for international cooperation in meteorological data collection, processing, and dissemination, to improve weather forecasting. The program has also been endorsed by the Congress of the United States in concurrent Resolution No. 67.

Recommendation:

Global oceanographic monitoring and prediction activities should be jointly planned with the World

Weather Program to provide a well-coordinated and non-duplicating global ocean-atmosphere monitoring and prediction system.

III. OTHER INTERNATIONAL ORGANIZATIONS

The Food and Agriculture Organization of the United Nations (FAO) is concerned with world fishery problems, and the influence of marine physical parameters on the location and extent of living resources. The FAO Fisheries Division was raised to the status of a department in 1966. The department now has two divisions: Fishery Resources and Exploitation, and Fishery Economics and Products. The first is concerned with scientific problems related to the evaluation of living resources, their relation to their environment, and with the scientific and technical problems of harvesting and management. It maintains the Fishery Data Center and the other division covers technical aspects of fishery resource utilization, development of statistical systems for resource assessment, fishery- related economic research, and training arrangements. In 1961 FAO established the Advisory Committee on Marine Resources Research (ACMRR) to advise FAO on marine fishery research, particularly the fishery aspects of oceanographic research; the ACMRR also serves in an advisory role to the IOC. At the Fourth Session of the ACMRR (Rome, Jan. 16-21, 1967) the Working Party on Fishermen's Charts and the Use of Synoptic Data distributed its draft report.[3] At the meeting, cooperation between fishing fleet operators and the WMO to secure additional meteorological data at sea was encouraged.

The International Maritime Consultative Organization, a governmental body, is primarily concerned with safety at sea under the Safety of Life at Sea (SOLAS) Convention—within which is included the International Ice Patrol. The operations of the International Ice Patrol are assigned to the United States, with funding shared internationally. IMCO has the responsibility for reducing oil spillages from tankers and other merchant shipping outside national territorial waters, and encourages research and protective measures to reduce such pollution. IMCO also has been active in establishing the legal framework for the stationing of floating stations (including buoys) in the open ocean, and cooperates with the WMO in encouraging weather reporting by merchant vessels. At its fifth Assembly in October 1967, IMCO adopted a resolution that invited member states to encourage owners and operators of ships sailing under their flag to participate in the voluntary weather reporting programs of the WMO.

The International Civil Aviation Organization has the "housekeeping" responsibility for the North Atlantic Ocean stations. Eight ships are maintained on station, four of them by the United States, to provide navigational references, and a search and rescue capability, in support of international aviation; the level of each nation's participation is based on its North Atlantic air traffic volume. All ships on station provide routine meteorological and surface oceanographic observations.

IV. APPRAISAL

As a result of a review of the activities of the international bodies active in environmental monitoring and prediction, the panel finds that the WMO has extensive "machinery" in operation for the collection of environmental data at sea. The plans of the IOC for the establishment of the IGOSS could result in much duplication of administrative and management mechanisms for the transmission of data in real time. The expendable bathythermograph makes it feasible to consider expanding the merchant ship weather reporting program to include subsurface ocean data. In addition, one of the important needs for ocean data is to improve weather prediction on land as well as sea.

Some of these pertinent considerations were recently stated in a Report of the Secretary-General of the United Nations Economic and Social Council:[4]

Great attention is being given by States members of WMO to expand the meteorological observational system over the high seas. The cost of this part of the meteorological network and its supporting facilities is very high and the incorporation of certain oceanographic observations in this

[3]Food and Agriculture Organization of the United Nations, Advisory Committee on Marine Resources Research, *Report of ACMRR Working Party on Fishermen's Charts and Utilization of Synoptic Data,* FAO Fisheries Reports No. 41, Supp. 2, Rome, Jan. 16-21, 1967.

[4]*Marine Science and Technology: Survey and Prospects,* Annex XIII, April 24, 1967, p. 6.

system requires urgent consideration if the cost effectiveness of the programme is to be maximized. Thus, it is urgent that oceanographers and meteorologists meet to co-ordinate the observational programme on moored and drifting automatic stations, on island and coastal stations and on ships of opportunity specially provided with observing personnel. This would permit maximum oceanographic utilization of the meteorological network. Meanwhile, oceanographers must ascertain their own requirements for a monitoring network, so that a scheme can be developed for supplementing the observations derived from the meteorological network where necessary. This supplementary network could be used to some extent both for oceanography and meteorological purposes.

It is therefore essential to ensure effective co-ordination of oceanographic and meteorological activities. A first attempt in this direction was made by the establishment of joint WMO/IOC working groups, but there is doubt as to the adequacy of such arrangements in view of the complexity of the problems involved and of the difference in the present international institutional arrangements, including funding. There is as yet no experience in joint action on important matters such as the desirability and design of a joint meteorological-oceanographic network. Because of the extremely close interrelationship of these two disciplines, it is essential and urgent that a mechanism be found for their immediate and effective joint action.

For these reasons, in any realignment of international organizations active in the marine field, consideration should be given to effective mechanisms for the conduct of activities related to the collection of physical oceanographic data requiring near real-time processing with similar meteorological activities. One possibility that should be considered is combining the WMO and proposed operational activities of the IOC. Extensive arrangements have been made by both the IOC and the WMO to assure adequate coordination between the two agencies. In regard to IGOSS there have been established joint IOC/WMO Panels of Experts on Coordination of Requirements, on Telecommunications, among others. The WMO has recently established an Executive Committee Panel on the Meteorological Aspects of Ocean Affairs.[5]

The close relationship between the physical, biological, and other aspects of oceanography, now facilitated by the present IOC-UNESCO organization is recognized. Further, there will continue to be research needs in physical oceanography that do not require rapid transmission of observed data that may be of relatively little significance in forecasting the behavior of the environment. For these reasons, the panel does not consider it appropriate to make a recommendation on this matter.

[5] WMO Executive Committee XX Resolution 17.

There are a number of potential payoffs to be obtained from an improved environmental monitoring and prediction system. The panel, in reviewing much of the material that has been prepared on this subject, has been forced to recognize the difficulty of prescribing dollar benefits that would be achieved by an improved system–it is indeed difficult to assess the dollar benefits associated with the existing system. This subject will require increasing attention as major expansions, involving relatively large expenditures, are contemplated.

Several operations which would be improved as a result of the expanded environmental monitoring and prediction system are presented below with limited estimates of dollar benefits.

I. FISHERIES

A major ocean-oriented activity affected by the quality of environmental predictions is the fishing industry. Fishing areas are affected by changes in ocean currents, temperature, and other physical and chemical parameters. The fisherman tries to anticipate these changes to improve his efficiency. The individual fisherman can only do this to a limited degree, although in some cases even this is worthwhile.

Among the parameters that are especially significant to the fisherman are sea-surface and subsurface temperatures, depth of the mixed layer and structure of the thermocline, and boundaries between water masses. The relationships of the harvestable fish to concentrations of their food organisms is also a potentially useful indicator, although not yet very well developed. For example, fishermen in the North Sea and Barents Sea can improve their location of herring by their own plankton collection, by exploiting the relationship between herring and the copepod *Calanus* on which it feeds.[1]

Forecasts of the position of critical isotherms (60-66°F) for albacore tuna fisheries off the U.S. Pacific Coast are now issued routinely by the Bureau of Commercial Fisheries, in cooperation with the Navy (a sample forecast is attached as Appendix B). Seasonal forecasts are issued in the spring, and are revised by daily advisories during the fishing season. Evidence to date has indicated that the fishing fleet has been able to make profitable use of this information by shifting their operations; processing plants use the seasonal forecasts to schedule their activities and shift sources of supply.

During one year's operations the major portion of the California albacore tuna fleet moved to their Oregon fishing grounds more than two weeks ahead of their normal schedule, as a result of advisories broadcast by the Bureau of Commercial Fisheries. It was estimated that this shift added approximately 1,350 to 1,800 tons to the season's catch, with a dockside value of \$585,000 to \$780,000.[2]

II. OCEAN TRANSPORTATION

The sea remains a major international transport highway, and will probably remain so for many generations. In 1967 imports to and exports from the United States in ocean-borne commerce totalled 386 million tons, with a value of \$37 billion.[3] The Maritime Administration now estimates the annual volume of cargo in international commerce with the United States to be 564 million tons, with a value of \$73.5 billion by 1980.[4] Many outputs of the environmental monitoring and prediction system have a direct bearing on shipping.

Better surface wave statistics should make it possible to improve the design and lower the cost of new ships; improvements in wave, wind, and current forecasts would permit improved minimum time ship routings. Improved sea-shore wave and current data should improve the design of harbor facilities.

[1]Schaefer, Milner B., Oceanography and the Marine Fisheries, *Canadian Fisheries Reports,* No. 5, June 1965, pp. 29-35.

[2]Flittner, Glenn A., 1967, Forecasting Availability of Albacore Tuna in the Eastern Pacific Ocean, presented at the 17th Annual Meeting of the International Commission for the Northwest Atlantic Fisheries, Boston, Massachusetts, May 30, 1967.

[3]Statistical Series of the Maritime Administration.

[4]Internal planning factors developed by Maritime Administration.

A. Ship Design

Wind-generated ocean surface waves produce the major strains on a ship, and the wave spectrum must be considered in design. Waves cause heavy slamming and propeller emergence that produces dangerous vibrations, and they are of basic importance in designing for freeboard, stability, and hull strength.

Loss of speed in heavy weather is a major factor in fuel consumption and power requirements. Better statistical descriptions of ocean wave properties are essential to design ships with higher payload/weight ratios and narrower tolerances. At present, this statistical information is not adequate as a yardstick by which to measure the degree to which test and model basins simulate the real ocean.

Recent reductions in new ship costs per cargo ton have been achieved by improvements in ship machinery and construction technology, but further reductions seem possible through improved design, resulting from increased understanding of the ship's physical environment.

In addition to the savings that could be effected by improving the design of conventional ships, radical departures in design now on the horizon, such as hovercraft, hydrofoils, and cargo-carrying submarines, will require improved and specialized environmental predictions. The impact loading on a hovercraft due to wave action is a major design factor; hovercraft on long voyages will require specialized routings to avoid strong winds and high waves.

B. Minimum Time Paths

The ability to forecast the propagation and decay of ocean waves is limited by the lack of theory-observation feedback. Increased data would enable the scientists to advance their theories and test them more adequately. Even with our present understanding of ocean wave phenomena, it is possible to predict the sea surface conditions to be encountered by a ship along any given route. Ships can be routed along a minimum time track, or routed for maximum comfort or safety. Such a program is now conducted by the Navy, as well as in other countries, on the basis of available data. Several commercial operators also use least-time track forecasts, usually prepared by private forecasting services.

Especially needed to improve these techniques are better knowledge of winds and currents near the sea surface, improved understanding of the generation, propagation, and decay of ocean surface waves, and the effects of waves on ships.

It is not yet feasible to estimate the overall potential savings to the maritime industry from a perfected ship routing program. From data covering MSTS ship routings during 1958, analyzed by the Naval Oceanographic Office, it was estimated that an average of at least $3,000 was saved per ship-crossing of the North Atlantic and North Pacific, due to a reduction of at-sea time.[5] In addition to time saved, there is a potential saving in improved ship routing by reducing storm damage to ships and cargo. The provision of ship-routing forecasts to commercial shipping lines by private consultants is further indication that the technique is economically worthwhile.

In addition to ships there are a growing number of stationary platforms at sea—oil-drilling rigs on the Continental Shelf are a prime example. Operation of such platforms requires improved forecasts of environmental parameters. Under certain conditions, the working crews aboard the platforms are removed; longer range, and more accurate predictions of those parameters associated with the decision to halt operations would provide a considerable dollar benefit to the operators.

III. LONG-RANGE WEATHER FORECASTING

A significant improvement in long-range weather forecasting requires improved understanding of the large-scale interactions between the oceans and the atmosphere. Such studies are presently hampered by a lack of data. Present long-range forecasting accuracy is fairly low, but it is clear that considerable economic benefit would result from any significant improvement in this capability. Several examples are: timing the planting and harvesting of crops; planning seasonal fuel transportation and storage, timing road construction, and flood and drought prediction.

Flood damage could be reduced by management of flood control structures, for example, by lowering the water levels in reservoirs prior to periods of heavy precipitation or snow melt. The

[5] Anon., How Optimum Routing Saves Shipper Services Millions, *MSTS Magazine,* Vol. 9, No. 11, November 1959, pp. 14-16.

magnitude of this problem can be indicated by data that show that the estimated damage from floods in the United States alone was $4.2 billion, an average of $280 million a year, over the 15-year period from 1946-1960.[6] Such data alone do not prove that a great benefit could be achieved by improved long-range forecasting, but it is clear that the potential exists for better decision-making based on improved forecasting to achieve sizeable dollar benefits.

Construction costs could be lowered by scheduling labor and equipment to take advantage of good weather. The costs of fuels and electric power used in space heating and air conditioning would be reduced if public utilities and fuel producers could plan production, transportation, and storage on the basis of reliable forecasts of warm or cold winters and hot or cool summers.

There are other, potentially much greater, benefits possible as the result of present-day atmospheric and oceanographic research. Meteorologists now believe that we are close to being able to achieve some measure of control over the weather. Hurricanes in the Atlantic and typhoons in the western Pacific are born and nurtured over the oceans. Research efforts are now underway to develop and test methods for blunting the intensity of these storms. Again, progress is hampered by a lack of suitable meteorological and oceanographic data. Potential benefits are great.

IV. REQUIREMENTS FOR COST-BENEFIT/ SYSTEMS STUDIES

In many areas of decision making, extensive use is made of techniques referred to as "cost-effectiveness analysis" and the closely-related methods of "systems analysis" or "operations research." At the present time, the application of such techniques to environmental problems has been rather limited. The techniques of systems analysis will have to be widely applied to the examination of alternatives in expanding the Nation's environmental monitoring and prediction programs.

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[6] Intergovernmental Oceanographic Commission, UNESCO, Draft of a General Scientific Framework for World Ocean Study, UNESCO, Paris (1964).

As these alternatives encompass increasingly sophisticated technology with associated cost increases, decisions to deploy major systems cannot be based primarily on intuition. The cost associated with the conduct of appropriate studies represents a relatively small fraction of the cost of some of the new hardware being considered, and becomes a relatively more easily justifiable expense. New technological development should not be delayed, but analyses should be undertaken in parallel to provide a suitable decision-making framework when advanced major systems are ready for implementation.

The proper selection of alternative schemes for improvement and expansion of the National Environmental Monitoring and Prediction System hinges on an approach that requires three types of studies that are conceptually relatively independent:

–Study 1. For the time table being considered, alternative methods of expanding the National Environmental Monitoring and Prediction System should be reviewed; this will primarily include alternative data acquisition systems, but may also include new communications and data processing facilities. The alternatives should be specified in as much detail as possible, including capability and operating cost data.

–Study 2. For the time period being considered, estimates should be made of the improvement in monitoring and prediction that can be achieved by each of the alternative sub-systems proposed in Study 1.

–Study 3. The economic benefits resulting from the improvements in the outputs of the monitoring and prediction system obtained in Study 2 should be estimated.

Study 1 would use technical data descriptive of new developments. The study would recognize that, in general, new technology is being considered as an "add-on" to the Nation's existing environmental monitoring and prediction system. This investigation should include parametric analysis of new data collection systems, to yield, for example, information on cost as a function of data accuracy so that the trade-off between numbers of systems deployed and data accuracy can be examined.

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Study 2 would concentrate on estimating the improvements in forecasting that would be achieved by adding the new sub-systems considered in Study 1, as well as the potential for forecasting parameters that are not now regularly predicted. It is in this area where the environmental scientist must make his strongest contribution. Some work has already been conducted in this field in connection with numerical (i.e., computer) weather prediction,[7] to establish criteria for required data density and accuracy, where the question has generally been limited to the acquisition of additional data similar to that already acquired, as well as data observing accuracy. Theoretical studies of the behavior of errors (i.e., perturbations) in the initial data field during forecast calculations have also been made.[8]

Similar analyses have been conducted to estimate the density and accuracy of observations required to describe adequately the sea-surface temperature structure. In one study[9] relationships were obtained between desired accuracy of the analysis, and the density and accuracy of observation.

At present, much of the expectation for improved long-range forecasts is based on the use of data not now available. Attempts should be made to simulate the effects on prediction performance of postulated new data. Where it is difficult to adequately test new hypotheses without adequate data, data collection experiments should be planned so that the impact of new data on prediction performance can be tested on as small a scale as feasible before making a committment to major new data-collection systems. Among the serious questions to be considered is the feasibility of modifying numerical forecasting techniques to include unconventional data collected by platforms now under development; for example, satellite observations which would yield average values of environmental parameters over fairly large areas, as opposed to the conventional point observations.

In many cases, the combined outputs of the first two studies would be extremely valuable. We would be able to relate the projected ability to forecast environmental parameters to proposed characteristics of the expanded environmental monitoring system. We would further be able to make statements relating system performance to increased cost.

In Study 3 we are faced with the problem of estimating benefits to various segments of the economy resulting from environmental prediction services. This is typically a difficult problem, and the panel has found a limited number of examples.[10] The strongest requirement is the development of a detailed understanding of the operation under study, rather than understanding the behavior of the environment. Thus, to study the impact of improved ocean temperature predictions on the fishing industry, it is more important to understand a particular fishing operation, and the dynamics of the fish population, than it is to understand the physics of the ocean's temperature structure.

Such studies may be initiated before the results of Studies 1 and 2 are available if reasonable improvements in the environmental prediction "products" are postulated. Such studies must concern themselves with realizable benefits in a given operation, as opposed to potential benefits.

Although the considerable difficulty in achieving benefit estimates is recognized, it is equally clear that proposals for increased major investments associated with the expansion of the National Environmental Monitoring and Prediction Service must be supported by estimates of the type outlined here. Decisions regarding deploy-

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[7]Alaka, M. A. and F. Lewis, *Numerical Experiments Leading to the Design of Optimum Global Meteorological Networks, Technical Memorandum WBTM-7,* U.S. Department of Commerce, ESSA, Washington, D.C., February 1967, 14 pp; Panel on Observations Over Sparse Data Regions, *Plan for Meeting Meteorological Observation Requirements Over Sparse Data Regions,* Technical Planning Study No. 1, U.S. Weather Bureau, Washington, D.C., 1963, 51 pp.

[8]Thompson, P.D., Uncertainty of Initial State as a Factor in the Predictability of Large Scale Atmospheric Flow Patterns, *Tellus,* vol. IX, No. 3, 1957, pp. 275-295.

[9]James, Richard W., *Data Requirements for Synoptic Sea Surface Temperature Analyses,* Special Publication, Naval Oceanographic Office, Washington, D.C., 1967, 29 pp.

[10]A. J. Russo et al., *The Operational and Economic Impact of Weather on the Construction Industry,* The Travelers Research Center, Inc., Hartford, Conn., 1965; Kolb, L. L. and R. R. Rapp, *Utility of Weather Forecasts to the Raisin Industry,* The RAND Corporation, Santa Monica, California, 1961; Demsetz, H., *Economic Gains from Storm Warnings: Two Florida Case Studies,* The RAND Corporation, Santa Monica, California, 1962.

ment of new technology are closely related to expected benefits.

Recommendation:

Extensive analyses of design trade-offs, intended use of resulting data in prediction, and benefits from improved predictions must proceed in parallel with major technical development programs. Such analyses are required to support decisions regarding operational deployment of major new systems.

Hearing Schedule

Date	*City*	*Host*
Oct. 9-12, 1967	Washington, D.C.	
Nov. 6-7, 1967	Boston	Massachusetts Institute of Technology
Nov. 8-9, 1967	New York	Ford Foundation
Dec. 4, 1967	Chicago	Federal Water Pollution Control Administration
Dec. 5-6, 1967	Seattle	University of Washington
Dec. 7-8, 1967	La Jolla	Scripps Institution of Oceanography
Jan. 10-11, 1968	Houston	Gulf Universities Research Corporation
Jan. 12-13, 1968	Miami	University of Miami

Persons Appearing at Panel Hearings

Elbert Ahlstrom, Senior Scientist, Bureau of Commercial Fisheries, Ocean Research Laboratory, Stanford, California

Dick Bader, Associate Director, Institute of Marine Science, University of Miami, Miami, Florida

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Appendix B **Temperate Tuna Forecast for 1968**[1]

The statements which follow constitute the eighth consecutive annual prediction to be issued for the summer season albacore and bluefin tuna fisheries off the Pacific Coast.

The merger of the former California Current Resources Laboratory and the Tuna Resources Laboratory to form the Fishery-Oceanography Center (see August, 1967, issue of this publication) has placed the former Tuna Forecasting Program as a project within a new Fishery-Oceanography Program. Although the mandate of the new program is broader than previously, our staff has yet to realize significant gains to date in either personnel or funds because of restrictions presently affecting Federal activities. Nevertheless, advances during the past year were made in the areas of environmental monitoring and prediction; these advances were in heat budget studies, the analysis of sea temperature anomalies, and in the interpretation and application of the wealth of data made available to us through the cooperative data exchange program between the Fishery-Oceanography Center and the Naval Weather Service's Fleet Numerical Weather Central at Monterey, California.

Satisfactory measurement of biological aspects of the temperate tuna populations and the effects of varying economic conditions has continued to lag far behind our progress in monitoring and understanding the environment. No meaningful progress has been made on the estimation of year-class strength, apparent fish abundance, and fishing effort for either albacore or bluefin tuna.

Early subscribers to this publication should note that these 1968 forecast statements are being made about 3-4 weeks later than in previous years. The delay in issuance of our predictions arises from experience accumulated during the past 8 years, which has shown that prediction techniques once thought to be valid have not withstood the test of time satisfactorily. Our prediction techniques were based upon the expected persistence of large-scale sea surface temperature anomaly patterns; consequently, the offshore thermal trends observed in April of each year were assumed to persist at least through the following month of July. Last year, this assumption failed: the abnormally cold conditions observed in April, 1967, were the basis for our predicting a late, more southern fishery than in 1966. Subsequently, intense early-summer warming completely overtook the previous cooling trend, and by July 15, abnormally warm conditions were established in the Pacific Northwest and then persisted for the remainder of the season. The albacore responded rapidly to these dynamic changes, producing near-record catches off Oregon and Washington while California experienced very poor fishing.

This experience dictates that we substantially alter our approach for the 1968 season. One major change will be the temporary suspension of long-term quantitative landings and area forecasts. The second major change will be to make heavier use of short-term projections of conditions based on current information issued in the form of outlooks and occasional bulletins. These bulletins which received highly favorable response last year, will include: changes in oceanographic and atmospheric trends; changes in location of productive fishing areas; changes in total fishing effort; and other data that are pertinent to the fishing community. As in previous years, the success of these operations necessarily depends upon the input of first-hand information from the fishermen at sea, dock operators and processors. Our staff continues to be hampered by a scarcity of timely information of this kind.

ALBACORE TUNA

Previous knowledge of the high correlation between catch and sea temperature, combined with an 8-year experience in observing and summarizing sea surface temperatures at 15-day intervals from April to October, provides us with the basis for depicting the shaded areas in Figure 1 The isotherm fields for the first and second halves of July represent our long-term averages for each interval. The shaded areas

[1]Bureau of Commercial Fisheries, Department of the Interior, *California Fishery Market News Monthly Summary*, Part II, *Fishing Information*, May 1968, pp. 1-5.

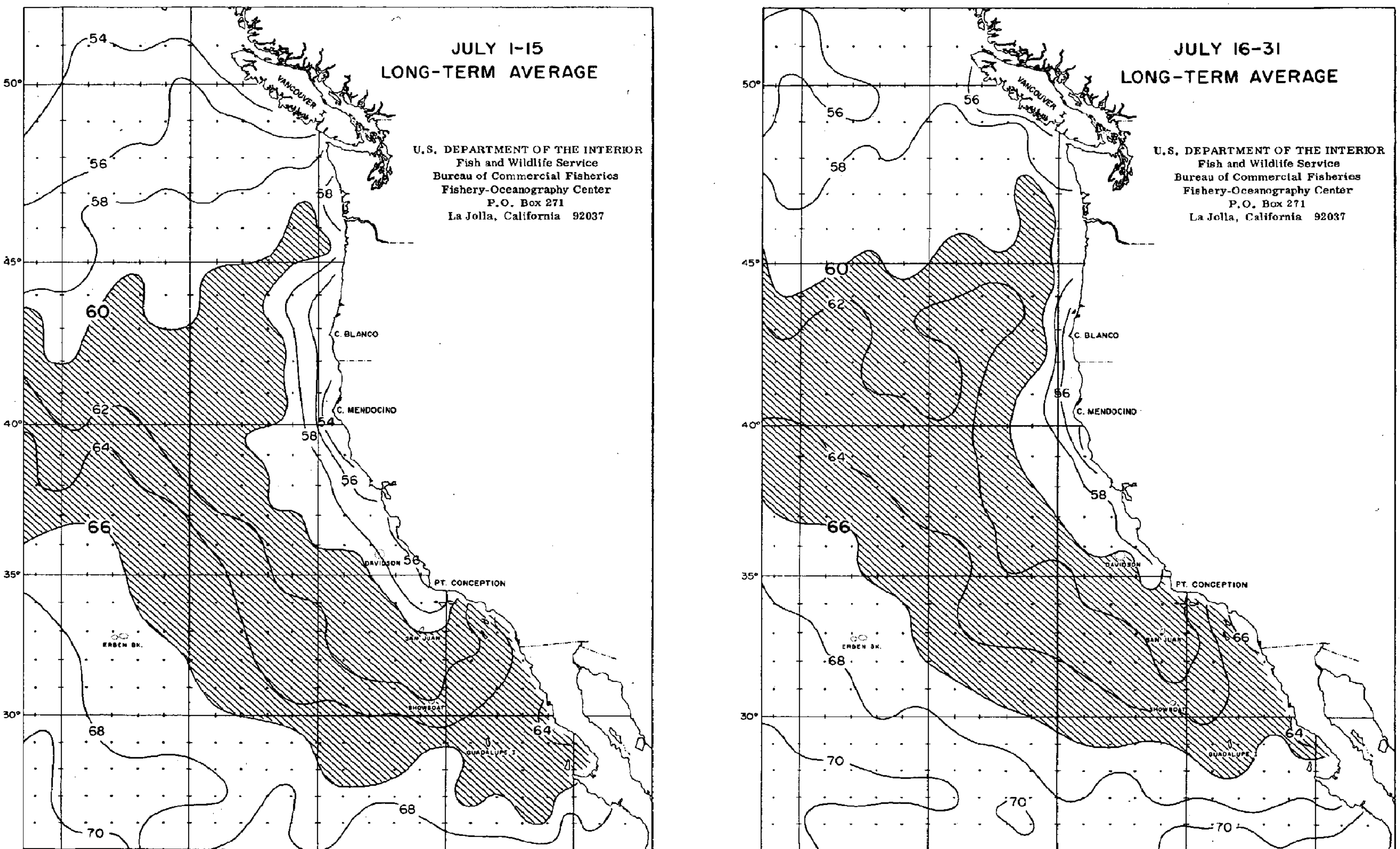

Figure 1. *Average sea surface temperature fields for the July 1-15 and 16-31 intervals. Shaded zone delineates region where most of the albacore would be available under these conditions.*

delineate the region where, *on the basis of sea temperature averages,* most of the albacore would be available in July. Since the prevailing weather and sea temperature patterns may deviate considerably from these averages during the period, we expect to have to modify and update our projections as conditions indicate; these will be forwarded to the fishing community as soon as practicable.

Preseason scouting activities will be minimal this year. The California Department of Fish and Game R/V *N.B. Scofield* is undergoing shipyard overhaul, and has been unable to embark on her usual May-June offshore scouting cruise. The loss of *Scofield's* valuable preseason participation has already resulted in substantial reduction of our ability to make early-season judgments based on data normally acquired during the cruise. The BCF R/V *David Starr Jordan* is presently at sea running the CalCOFI sardine-anchovy survey grid lines and is trolling for albacore in the nearshore region from Punta Eugenia, Baja California, northward to off Monterey Bay before returning to port on June 22. *Jordan* first reported taking four albacore near San Juan Seamount (33° N, 121° W) on June 12. This catch is the first authenticated report available this season, and suggests that the fish may be arriving on the Pacific Coast feeding grounds up to 2-3 weeks earlier than in the past 3 years.

The open ocean in the region encompassing the general migratory route of albacore (130-150° W) has shown large-scale warming trends in late May and early June. Thus, if the warming trend continues, we expect to see an appreciable portion of the incoming migrants diverted into northern waters instead of southern California. The Guadalupe Island area and the region to the northwest may produce some early-season catches, but we expect the fishery to advance rapidly northward from San Juan Seamount to west of Davidson Seamount by the end of July.

July landings in southern California should reflect a return to more normal conditions and be near the 1940-66 average of about 6,600,000 pounds (3,300 tons). Total California season landings cannot yet be estimated, but we expect that they may also fall near the 1940-66 average of 30,000,000 pounds (15,000 tons).

The Oregon-Washington region is expected to receive a significant portion of the total U.S. West Coast albacore production this year, but total landings are expected to fall somewhat below 1966-67 levels.

The BCF R/V *Jordan's* recent early-season albacore catch continues to demonstrate the value of preseason scouting cruises to determine the arrival time of the albacore tuna in Pacific Coast offshore waters. Even if successful forecasting of environmental conditions were possible, knowledge of these trends would not necessarily enable us to predict the availability of the fish in both time and space. Without having additional life history and other vital statistics from the entire North Pacific albacore population, we can make only certain conclusions which are based on other information sources.

R/V *David Starr Jordan* is scheduled to survey the northern California-southern Oregon offshore region from July 15 to August 16. Major objectives of this cruise will include establishing the distribution and availability of albacore in offshore waters during the middle of the Pacific coast season, and to test prospects for commercial exploitation of albacore beyond the traditional limits of the fishery (about 300 miles). During the cruise, pertinent information will be radioed daily to WWD for re-broadcast as part of the daily albacore fishing information summary. The information gained from *Jordan* should be of prime value to fishermen and processors in updating mid-season projections this year.

BLUEFIN TUNA

The high-seas purse seine fleet has already begun intensified scouting in the Cape San Lazaro-Cape San Lucas, Baja California offshore region. Boats returning from the yellowfin fishing area south of Cape San Lucas have reported sighting bluefin "jumpers" in cold, green water near Cape San Lucas and northward to near Point Tosco in the past 2 weeks. In addition, one sportfishing boat recently reported taking a few 10-15 pound bluefin in the Guadalupe Island area, about 400 miles to the northwest.

In recent years, bluefin fishing activity has commenced in lower Baja California by the last week of May. This year, however, the fishery is expected to develop later than usual because of significant changes in climatological events in that region. To date, lower Baja California has experienced a spate of strong northerly winds. The heavy weather created by these winds has severely limited fishing activity and has caused greatly-intensified upwelling. This upwelling has created a nearshore band of considerably colder than normal sea temperatures and green water. These events have combined to delay the onset of the fishery well into the month of June, and may cause the bluefin to remain farther offshore than usual.

One consequence of the delay in commencement of the bluefin season will be a northward shift in the center of production and a delay in the period of maximum production. Rapid warming in the region north of Guadalupe may cause bluefin tuna to appear earlier than last year in southern California offshore waters.

Meaningful estimates of total 1968 bluefin landings are not available. We have no data on which to make projections of abundance. Likewise, we are unable to forecast fishing effort which will be diverted to bluefin because of uncertainties associated with the establishment of a closure date terminating fishing for yellowfin tuna.

June 13, 1968 Staff, Fishery-Oceanography Program

The coastal zone is the transition area between the land and the sea. Its resources and use must be carefully developed for the benefit of present and future generations. (Bureau of Sport Fisheries and Wildlife photo)

Report of the Panel on Management and Development of the Coastal Zone

The Nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value.

* * *

Conservation means development as much as it does protection.

Theodore Roosevelt

This Panel Report deals with environmental problems, management, and development of the coastal zone. The decision that the coastal zone should involve a separate report was based on the public attention and concern recently focused on this environment and the awareness that our coastal waters are a vital National resource being subjected to the growing pressures and conflicts of a burgeoning modern economic and industrial society.

Therefore, we have compiled a report examining in detail the many uses of the coastal zone, the roles played by the participants, and both the natural and man-made problems of this environment.

A large part of the fact finding and study was done in close concert with the Panel on Basic Science. We found from the outset that the problems of the nearshore environment are inescapably related to the fundamental sciences underlying them.

Information was gathered by the panel in several ways, chiefly through informal hearings held in various parts of the Nation. A total of 126 persons testified, representing the Federal Government, coastal States, research institutions, and industry. Appendix A lists the schedule of hearings and those persons appearing, to which the panel is highly indebted.

In a further effort to solicit the views of experts on the nearshore environment, over 600 individuals were corresponded with or interviewed. Their response contributed greatly to the panel's work and are gratefully acknowledged by the listing in Appendix A.

The panel also was aided greatly by many reports and documents generously provided by agencies, institutions and associations too numerous to list. Reports and references upon which much of our studies have been based are cited throughout the text.

We are indebted particularly to consultants and reviewers whose time and efforts have contributed significantly to this report. They, along with the staff membership, are listed in Appendix A.

The report contains 10 chapters and several appendices of related data and tabular material. Chapter 1 defines the scope and importance of the coastal zone.

Chapters 2 and 3 detail uses of the coastal zone and subsequent results. Chapters 4 through 6 emphasize pollution, transportation, and research.[1] A review of the activity of Federal agencies is given in Chapter 7, along with a summary of State activity. Chapter 8 discusses the complex arrangement of laws of the coastal zone.

Chapter 9 presents the panel's basic assessment of what should be done. Obviously it was not possible to include every recommendation or requirement considered and even discussed in earlier chapters.

Finally, in Chapter 10 we propose a National program for a State-Federal partnership in the management and development of the coastal zone.

John A. Knauss, *Chairman*
Frank C. DiLuzio
Leon Jaworski
Robert M. White

[1]Such important coastal zone roles as recreation, fishing, petroleum, and mining are the principal subjects of other Panel Reports.

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The coastland of the United States is, in many respects, this Nation's most important and valuable geographic feature. It is at the juncture of the land and sea where industrial development is heaviest and the greater portion of our trade takes place. The shoreline is the most popular locale for residence and recreation. The waters off the shore are among the biologically most productive regions of the Nation. The uses of valuable coastal areas generate issues of intense local interest. Yet the effectiveness with which we use and protect the resources of the coastal zone is also a matter of National importance. Economic development, recreation, and conservation interests are shared by the Nation and the States.

In view of the many important uses served by these waters and the growing pressures on them, intelligent management of this vital National resource is imperative. It will require application of many kinds of tools and techniques, ranging from fundamental research to regulatory changes and public education. A National policy for the management of our coastal environment is urgently needed.

This panel's recommendations are summarized under five categories:

–The Need for Planning and Management

–The Need for Research and Training

–The Need for Federal Surveys and Projects

–The Need for a Systematic Approach to Waste Management

–The Need for Immediate Action

I. THE NEED FOR PLANNING AND MANAGEMENT

Man's past actions affecting estuaries and shorelines have been poorly and incompletely planned, often unimaginative and frequently destructive. Present priorities in uses of the coastal zone often do not reflect the best interests of the public. Many State and Federal agencies have overlapping and fragmented authority. The limit of State and local responsibility is often obscure; the authorities are often without real power. Under such circumstances it is particularly difficult for plans to be designed, made authoritative, and enforced. Viable mechanisms to manage these areas must be established both at the Federal and State levels. In general, State leadership is to be favored. Each coastal State should develop a strong organization which can deal with the powerful and often conflicting local interests and with the many Federal agencies with interests in the coastal zone.

Recommendations:

1. Federal legislation should establish *State Coastal Zone Authorities* whose functions shall include planning, regulation, (including zoning where necessary), funding, acquisition, development, and enforcement.

2. The Coastal Zone Authority should be a State agency. The form of the agency may be left to the discretion of the States, but its guidelines must meet Federal standards and approval to be eligible for Federal assistance.

3. The Federal role should be to establish standards based on National surveys; to provide technical assistance; to provide matching Federal grants for coastal land acquisition, research, development, and enforcement; to assist State acquisition and development through bond guarantees; and to review Federally financed State programs for standards of performance. Further, Federal funding should be initiated to provide annual assistance to State Coastal Zone Authorities in the following amounts: $2.5 million for planning and operation, $2 million for enforcement, and $25 million for coastlands acquisition.

4. Interstate problems should be solved by the appropriate State Coastal Zone Authorities acting through interstate and regional commissions and compacts. The Federal Government should act as a mediating and review authority in interstate matters.

5. Marine sanctuaries or preserves should be established to protect and manage endangered areas

identified by National and State surveys and for ecological base-line studies. In general, State jurisdiction of any proposed sanctuary is favored. However, specific rare environments are a special National resource which may need to be protected and managed by the Federal Government, and the Department of the Interior should continue to acquire and manage such areas.

6. Management and development of the shoreline and Continental Shelf requires that State and shoreline boundaries be precisely determined based on geographical coordinates. This should be accomplished by a Seashore Boundary Commission working in conjunction with the U.S. Coast and Geodetic Survey, other affected Federal agencies, and the coastal State. Authority of such a commission should include making proposals for clarifying whether artificial structures should affect offshore boundaries; the impact of natural and artificial coastline changes caused by erosion, accretion, storms, and other processes; and how best to resolve conflicts that will arise.

II. THE NEED FOR RESEARCH AND TRAINING

Effective management and development of our coastal waters, lands, and resources require that man understand and predict the consequences of his actions. Although our understanding has increased markedly in the past 20 years, it is far from complete. The problems of the coastal zone are diverse and require the talents of economists, sociologists, engineers, ecologists, and community planners. Although the problems are similar from one part of the country to another, each estuary is different and requires study peculiar to its individual characteristics. Moreover, manpower must be trained to conduct and apply research in both management and development. The Sea Grant concept appears well designed to meet these needs.

Recommendations:

1. A coastal zone research institution devoted to basic and applied marine science should be located in every coastal State and affiliated with one or more academic institutions. These research laboratories need not be large but should have adequate facilities and staff to maintain a stable program. These groups can provide many of the studies and information upon which Federal, State, and local governments can base their management procedures.

2. The National Sea Grant College and Program Act of 1966 provides a suitable mechanism for supporting the work of the coastal zone laboratories here envisioned. Accordingly, Sea Grant funding for coastal zone research should be increased over the next 10 years to provide, in addition to other Sea Grant programs, institutional support for 30 coastal laboratories at an annual rate of about one-half million dollars each.

3. In addition to institutional support for coastal zone laboratories, Sea Grant funding should be further increased to provide support for research problems and manpower training related to the coastal zone at an annual level of about $12 million.

4. Two marine preserves should be established on each coast reserved for ecological base-line studies. These areas should be identified by the National inventory and studies now being conducted by the Department of the Interior. They should be managed by the Federal Government.

III. THE NEED FOR FEDERAL SURVEYS AND PROJECTS

Sound management and development of the coastal zone will require the benefits which large Federal surveys and projects are able to provide. These do not, however, replace the more detailed continuing studies at a regional or State level which can focus on individual problems. The Federal Government often must take the initiative in projects to demonstrate the feasibility of or to develop the technology. While comprehensive recommendations of all surveys of importance to the coastal zone are not possible, we have singled out several of special significance.

Recommendations:

1. There should be a comprehensive inventory of estuaries, coastal waters, and the Great Lakes. The survey should consider all phases of use, development, and preservation of the coastal zone. Balanced consideration should be given to potential for commercial, industrial, recreational, and urban development. The Department of the Inte-

rior presently is conducting two similar studies by different agencies of that Department. These studies should supplement one another to achieve the foregoing goals and the broad purposes of their legislation.

2. A National Port Survey should be conducted by the Department of Transportation in cooperation with the Departments of Army, Commerce, and Housing and Urban Development to define the Nation's requirements in terms of major ports, offshore terminals, and other facilities for maritime commerce. On the basis of this National Port Survey, a rational scheme for port and harbor development can be established against which the real needs of this country can be measured.

3. The National Port Survey should examine closely the Federal-local cost sharing relationships to determine whether the local government should be a stronger participant in the development of its port facilities.

4. Much of our Nation's shorelines are eroding, and are inadequately protected. The causes are both natural and man made. There is required a thorough survey of our beach resources and the practices which endanger them. The Corps of Engineers has been authorized to conduct such a study. Funding is required. Such a study should include a review of Federal-local funding arrangements and set standards for shoreline protection and regulation.

5. The water quality problems and the effects of eutrophication are becoming increasingly apparent in the Great Lakes and especially Lake Erie. Urgent and immediate action ranging from pollution abatement to lake restoration is required. Abatement is under way under the leadership of the Department of the Interior and local authorities. Restoration is not. Experimental programs in lake restoration should be explored and a project undertaken leading to an attempt to restore Lake Erie.

IV. THE NEED FOR A SYSTEMATIC APPROACH TO WASTE MANAGEMENT

The coastal zone is the ultimate sink for many of our waste products. The capacity to receive these wastes is being exceeded. In many of the coastal zone areas pollution is the single most important problem. It is the one problem in which there is the greatest public awareness, and it is one problem about which there is the most action at all levels of government. It is evident that the people of this Nation are upset about pollution and they aim to do something about it. The problems of pollution, however, are more than marine problems. While manifestly acute in our estuaries, Great Lakes, and nearshore waters, the problem is a total National one wherein water, land, and air pollution should be treated together and at the sources which often lie far from the coastal zone.

Recommendations:

1. Municipal sewage is one of the greatest sources of pollutants in estuaries. Only through modern, efficient sewage treatment plants can this be abated. Federal funding has been proposed and authorized by Congress but the money is not being appropriated as authorized. As a matter of National urgency, Federal funds for assistance in waste treatment works should proceed without delay at full authorized levels.

2. The advent of secondary and tertiary treatment in sewage disposal plants requires greater proficiency of operator capability. Present problems are often traced to careless and inexperienced operation. State health agencies should aid in training of and require certification for operators of waste treatment plants.

3. Although the oceans' capacity to assimilate wastes is immense, it must not be considered the ultimate solution. The full effects of dumping wastes at sea or the use of ocean outfalls for disposal must be better understood. The Corps of Engineers, which regulates dumping at sea; State health agencies; and the Federal Water Pollution Control Administration should take immediate steps to study these effects and institute adequate controls.

4. The Secretary of the Interior should prepare biennial reports of the pollution level of each of the Nation's estuaries and tell how it relates to the progress the various States are making in their pollution abatement programs under the Water Quality Act of 1965.

5. In final analysis, pollution of coastal waters is only one part of a National waste management

problem involving the interlocking effects of air, land, and water and complex economic and social issues. Burning wastes instead of dumping them in streams alleviates the water pollution problem but may create an air pollution problem. The farmer who sprays his field with pesticide is not responsible for this material when it drains into the estuary, and he has little economic incentive to search for alternative methods of insect control. A total integrated approach to waste management is necessary, and there should be established a National Commission to study and deal with the total waste management problem.

V. THE NEED FOR IMMEDIATE ACTION

Our knowledge of the coastal area is incomplete and will remain so for some time. It will probably take a number of years before an adequate management system is developed and translated into legislation. In the meantime, pressures of development and competition will accelerate. Although new legislation is required in some areas, there are laws which, although perhaps in need of amendment, still can be used effectively if enforced promptly and vigorously. In addition, recommendations of other groups which have studied these problems should be adopted. Urgency is the keynote.

Recommendations:

1. The Rivers and Harbors Act of 1899, administered by the Corps of Engineers, is the major Federal control over development of the coastal zone. The basis for Corps permits under this Act is the effect of the proposed development on navigation. This Act should be amended to empower the Army Corps of Engineers to deny a permit in order to preserve important recreation, conservation, and aesthetic values or to combat pollution.

2. The Federal Water Pollution Control Act has resulted in the establishment of water quality standards which become both State and Federal law. This is a major step forward in controlling pollution in our coastal waters. State agencies must develop and implement enforcement capabilities. The Federal Government should assist and back up State enforcement capability through funding assistance and the development of monitoring technology.

3. The Oil Pollution Acts of 1924 and 1961 should be amended to resolve jurisdictional control and to provide for equipment certification and liability of polluters. Pending such amendments, present laws should be enforced to the fullest. This responsibility is shared by the Federal Water Pollution Control Administration, the Coast Guard, and the Army Corps of Engineers.

4. Executive Order 11288 directs that Federal agencies comply with water quality goals in the construction and operation of Federal facilities and in awarding Federal grants and contracts. Action to meet this directive must be increased. Agencies such as the Atomic Energy Commission should apply this directive in its licensing procedures. Enabling legislation should be enacted if necessary.

5. The amount of shoreline available for public use should be doubled over the next 10 years. Priority should be given to near metropolitan areas where public areas are most urgently needed. More imaginative attempts are required to integrate recreational projects with other uses of the coastal zone such as conservation and industrial uses.

6. Non-uniform and often conflicting State boating laws confuse a burgeoning recreational boating public. Model State boating laws have been proposed through the National Association of State Boating Law Administrators. These laws should be adopted by the States.

7. A review of boating accidents shows that increased public education and enforcement of boating laws, and not further regulatory licensing, is the more effective path to recreational boating safety. The Coast Guard and State agencies should increase their efforts in that direction.

8. Improved mapping, charting, and navigation systems are essential to the safety and separation of activities competing for use of the coastal zone. They are also necessary for the orderly research and development of resources. The Coast Guard should take the lead in developing and installing a precise electronic navigational system with an accuracy in the order of ± 50 feet up to 200 miles from shore.

9. The increasing number of offshore structures and the growing size and hazardous nature of ships' cargoes necessitate ship traffic control pro-

cedures. The use of methods such as sea lanes and fairways should be extended to all congested areas. Authority for regulation and enforcement should be vested in the Coast Guard.

10. The Federal jurisdiction on the Continental Shelf should include the regulation of all fixed structures both surface and subsurface, including pipelines, wrecks, and lost or abandoned property. This jurisdiction should include considerations of navigation, safety, resources development, conservation, and pollution. These recommendations can be accomplished by amending the Submerged Lands Act and Outer Continental Shelf Lands Act.

11. Conflicting and often obsolete State fisheries laws aggravate a rational balance of use which is detrimental to industry, wise conservation, and other uses of the coastal zone. A legal framework relating to the coastal fisheries should be established through the medium of regional fisheries commissions which are sufficiently species oriented, non-discriminatory, and rooted in scientific knowledge. Uniform State laws should result.

I. DEFINITION

The coastal zone is a region of transition between two environments, the land and the sea. The coastal zone has been defined as that part of the land affected by its proximity to the sea and that part of the ocean affected by its proximity to the land. In addition to the shoreline, the coastal zone includes the inshore part of the Continental Shelf seaward and the estuaries landward. It also includes the Great Lakes. The Marine Resources and Engineering Development Act of 1966[1] defined the area as:

(a) the oceans, (b) the Continental Shelf of the United States, (c) the Great Lakes, (d) seabed and subsoil of the submarine areas adjacent to the coasts of the United States to the depth of two hundred meters, or beyond that limit, to where the depths of the superjacent waters admit of the exploitation of the natural resources of such areas, (e) the seabed and subsoil of similar submarine areas adjacent to the coasts of islands which comprise United States territory, and (f) the resources thereof.

For this report the coastal zone is taken as the immediate shoreline, the Continental Shelf, estuaries, and the Great Lakes.

II. THE SHORELINE

The immediate shoreline is the most visible part of the coastal zone–and the most turbulent. Shown by Table 1, the total coastline of the United States may be represented as 17 or 101 thousand miles in length depending on the definition of detail.

Within the U.S. coastline ranging from the Alaska Arctic to Florida Tropic can be found virtually all the classic coastal landforms.[2]

[1] P.L. 89-454, 33 U.S.C. 1107.

[2] A presentation of coastal landforms is contained in *Natural Coastal Environments of the World*, W. C. Putnam *et al.*, Office of Naval Research Contract, 1960, (Nonr-233(06), NR 388.013).

Table 1
LENGTH OF COASTLINE OF THE UNITED STATES, BY COASTAL REACH
(Statute miles)

Coastal Reach	General[1] Coastline	Tidal[2] Shoreline	Tidal[3] Shoreline Detailed
Atlantic Coast	2,069	6,370	28,673
New England	(473)	(1,395)	(6,130)
Middle Atlantic	(285)	(947)	(4,112)
Chesapeake	(143)	(1,019)	(6,505)
South Atlantic	(1,168)	(3,009)	(11,926)
Gulf Coast	1,631	4,097	17,141
Pacific Coast	7,933	17,542	41,767
Hawaii	750	900	1,052
U.S. Territories & Possessions	729	820	1,487
Total U.S. Seacoast	13,112	29,729	90,120
Great Lakes	4,678	–	10,980
Exterior and Interior Coastlines	17,790	33,262	101,100

Source: Information for this table was prepared in part by Surveys and Research Corp., 1967, for the National Council on Marine Resources and Engineering Development, based on data from Department of Commerce, Coast and Geodetic Survey, and Department of Defense, Corps of Engineers (for Great Lakes information). For more detailed data by States, see Tables 1 and 2, Chapter 2.

[1] Measurements were made with a unit of 30 minutes latitude. The corresponding mileage varies slightly, but at the latitude of San Francisco, 30" is about 34.5 miles. Shoreline of bays and sounds is included to where such waters narrow to the width of the unit measure, and the distance across at such point is included.

[2] As above, except that a unit measure of three statute miles was used.

[3] As above, except that a unit measure of 100 feet was used.

III. THE CONTINENTAL SHELF

The Continental Shelf generally has been recognized as the waters and seabed extending seaward from the coastline to about 100 fathoms (600 feet), where the sea floor commences a steep slope to the ocean depths. The shelf's width is approximately 50 miles but varies considerably depending on geomorphology. The shelf has been given new importance in recent years by the ratification of the International Convention of the Continental Shelf in 1958. Here the shelf was defined as:

The seabed and subsoil of the submarine areas adjacent to the coast but outside the area of the territorial sea, to a depth of 200 meters (657 feet) or, beyond that limit, to where the depth of the superadjacent waters admits of the exploitation of the natural resources of the said areas; to the seabed and subsoil of similar submarine areas adjacent to the coasts of islands.

The United States, under the terms of this convention, acquired the right to exploit shelf resources extending over an area of 850,000 square miles, roughly equivalent to the 1803 Louisiana Purchase.

The area of the U.S. Continental Shelf is shown in Table 2.

IV. ESTUARIES

The Coastal Zone's third major domain, the estuaries, comprizes the landward boundary of the land-sea transition zone. Historically the term "estuary" has been applied to the lower tidal reaches of a river. The broader contemporary definition may include bays, sounds, inlets, fjords, and lagoons. Estuaries have been variously defined and classified by geomorphology, circulation, salinity, origin, biology, and politics.[3]

The Clean Water Restoration Act of 1966[4] established the following definition:

For the purpose of this subsection, the term 'estuarine zones' means an environmental system consisting of an estuary and those transitional areas which are consistently influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and intertidal areas, bays, harbors, lagoons, inshore waters, and channels, and the term 'estuary' means all or part of the mouth of a navigable or interstate river or stream or other body of water having unimpaired natural connection with open sea and within which the sea water is measurably diluted with fresh water derived from land drainage.

It is the estuaries which experience the greatest impact of man's effect on the coastal zone. Consequently, most current attention being directed at the coastal zone is focused on the Nation's estuaries and the Great Lakes. Table 3 shows the areas of U.S. estuarine waters by region.

Table 2
AREA OF THE UNITED STATES CONTINENTAL SHELF BY COASTAL REGIONS
(Thousands of square statute miles)

	Area measured from coastline bounded by		
	3 Nautical Mile Band	100 Fathom Contour	1,000 Fathom Contour
Atlantic Coast...	6	140	240
Gulf Coast...	5	135	210
Pacific Coast...	4	25	60
Alaska Coast...	20	550	755
Hawaii ..	2	10	30
Puerto Rico and Virgin Islands...	2	2	7
Total....	39	862	1,302

Source: Information for this table was prepared in part by Surveys and Research Corp., 1967, for the National Council on Marine Resources and Engineering Development, based on data from Department of Commerce, Coast and Geodetic Survey, and Department of Defense, Corps of Engineers (for Great Lakes information). For more detailed data by States, see Tables 1 and 2, Chapter 2.

Table 3
ESTUARINE AREAS

Region	Area (Square Miles)
New England	3,149
Middle Atlantic	6,719
Chesapeake	1,688
South Atlantic	14,359
Gulf of Mexico	3,837
Pacific	19,680
Great Lakes	60,306
Total estuarine ...	109,838

Source: Figures based on Coast and Geodetic Survey. Based on "low water line mapping," they may not include marshlands and certain "inland waters." For a complete discussion of these and other statistics, refer to *Shore and Sea Boundaries,* A. L. Shalowitz, U.S.C.&G.S. Publication 10-1, 1964.

[3] A discussion of the definition and terminology is contained in *Estuaries,* Publication No. 83 of the American Association for the Advancement of Science, 1967, particularly Section I: papers by D. W. Pritchard, Hubert Caspers, and K. O. Emery.

[4] 70 Stat. 499, 33 U.S.C. 466c. This Act directs that a National Estuarine Study be conducted. See Chapter 9.

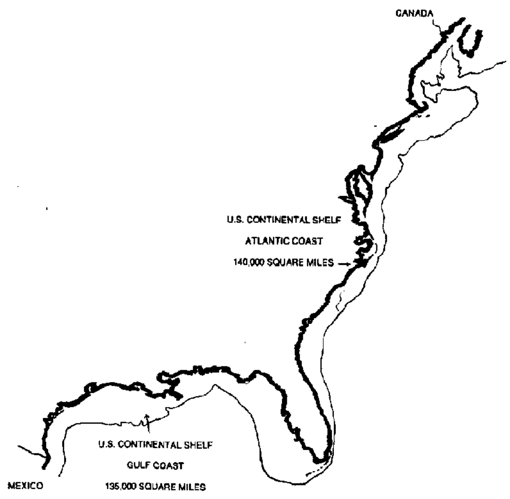

Figure 1.

V. JURISDICTIONS

Within the limits of the coastal zone are five jurisdictional belts. Bays, estuaries, and other semi-enclosed areas are classed as *internal waters.* Over these, individual States have jurisdiction; in some cases the States have transferred this jurisdiction to counties or municipalities. Seaward of the internal waters, and of the low-water line along uninterrupted coasts, is the *territorial sea,* extending to three miles from shore. Here again, individual States have ownership over the waters, the seabed, and the subsoil.[5] Between three and twelve miles from the shore is the *contiguous zone* in which the Federal Government may act to prevent the infringement of certain laws, particularly those relating to customs, immigration, and sanitation. Within this zone, also, the United States exercises exclusive fisheries rights; foreign vessels are enjoined from fishing in this area unless by special agreement. Except for these provisions, the contiguous zone, together with the waters which lie seaward of it, has the status of the *high seas,* accessible to all nations.

The seabed and subsoil beyond territorial limits are known as the "Outer Continental Shelf" and are under the jurisdiction of the Federal Government. The shelf extends out to the 200-meter isobath (657 feet), although nations may claim jurisdiction beyond this limit if they are capable of exploiting the resources of the seabed and subsoil. To date, the U.S. Government has not officially claimed control beyond the 200-meter line.

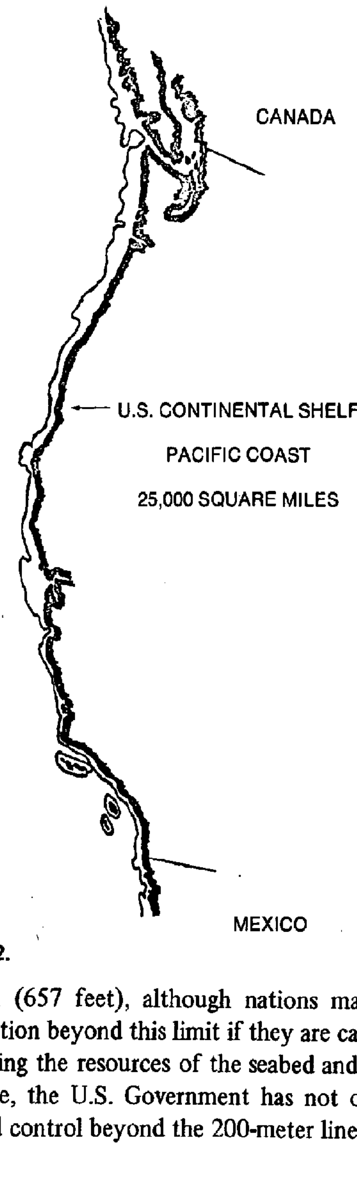

Figure 2.

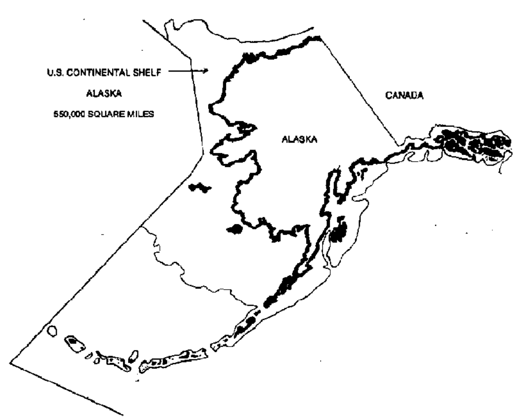

Figure 3.

[5]Both Texas and Florida, along their Gulf coasts, have State boundaries extending out to nine nautical miles from shore on the basis of "historic rights." The breadth of the territorial sea off Louisiana is being reviewed in the courts.

VI. THE GREAT LAKES

The Great Lakes are included within the scope of this report under the provisions of the Marine Resources and Development Act of 1966.

Within the boundary of the States of the United States and the provinces of Canada which adjoin the Great Lakes is an area with a population of 55 million. It is the source of almost 80 per cent of the steel, 40 per cent of the agricultural produce, and the greater part of the equipment and products of heavy industry made in the United States and Canada. Much of the growth and potential of this region is based on the vast Great Lakes waterways which, until 1959, had no link to the ocean for the passage of deep-draft vessels.

When the St. Lawrence Seaway was officially opened on June 26, 1959, making the Great Lakes accessible to such vessels, a fourth U.S. seacoast was created that added even more potential to the heartland area of this country and also of Canada.

The Lakes contain the largest mass of fresh water on the earth's surface, and represent approximately 40 per cent of the surface waters of the continental United States. Furthermore, their combined area of 95,170 square miles is about the same as that for each of the following seas: Persian Gulf, English Channel, Gulf of California, and the Irish Sea. Because of their size, they frequently are referred to as inland seas, laboratory sized oceans, and the mid-continental coastal area.

The maximum lengths of the Lakes range from 350 miles (Superior) to 193 miles (Ontario); maximum breadths range from 183 miles (Huron) to 53 miles (Ontario); maximum depths range from 1,333 feet (Superior) to 210 feet (Erie); and the mean depths range from 487 feet (Superior) to 58 feet (Erie).

The Great Lakes are subject to essentially the same physical, chemical, biological, meteorological, and geological regimes as the oceans, but, in addition, possess definite boundaries and each generally has a single weather system over it at a given time. Furthermore, the Great Lakes drainage basin is a discrete physiographic unit, within which exist integrated social, political and economic regimes directly dependent upon the Lakes.

VII. SOCIOECONOMIC TRENDS

Seventy-five per cent of our population now lives in States bordering the ocean and the Great Lakes. This population is growing at a faster rate than the total U.S. population. There is developing a nearly continuous urban concentration along the Atlantic Ocean from Boston to Norfolk. The same phenomenon is appearing along the California

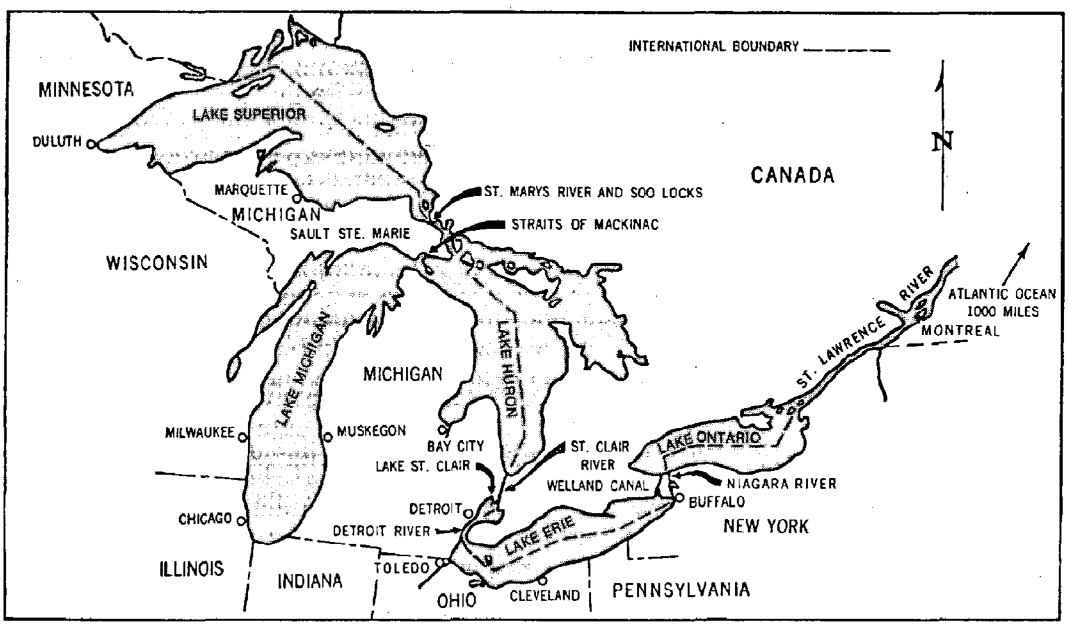

Figure 4. *The Great Lakes–America's fourth seacoast.*

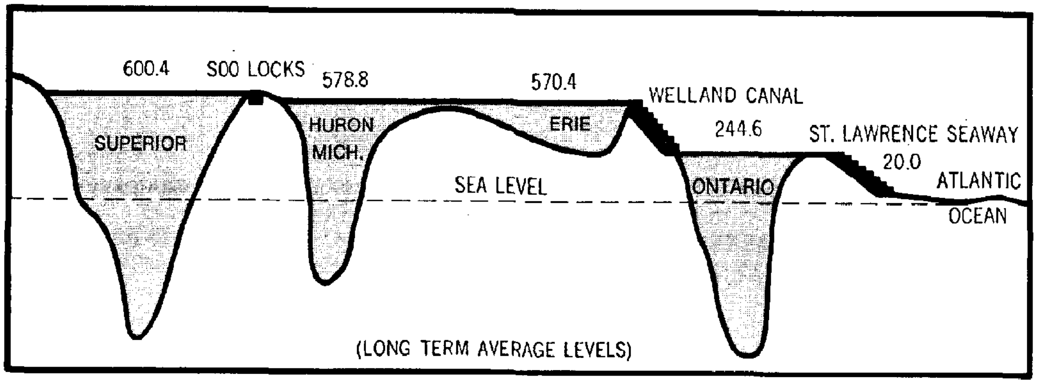

Figure 5. *Profile of the Great Lakes and the St. Lawrence Seaway.*

coastline and in the central Gulf Coast, as well as along Lake Michigan and Lake Erie.

Before the new concentration of people living year round in our coastal cities, the seashore was a favorite site for seasonal recreation. Currently, water-based recreation is one of the fastest growing activities, and shows no sign of leveling off. Greater leisure, easier access to water, improvements in such facilities as small craft harbors and marinas all are contributing to this trend.

The coastal zone is also the site of increasingly important economic activity. Traditionally, the coastal zone has been the staging area for transfer of goods to maritime transportation. Storage functions near ports, and shipbuilding and vessel services were located in the coastal zone very early in our history. Industries utilizing water transportation have located in the coastal zone, and on navigable rivers, in response to the competitive economics of location.

Within the last 20 years the offshore production of oil, gas and sulfur have become major industries as well as a major factor in considering uses of the coastal zone. Although we do not yet know the full extent of offshore petroleum reserves, they appear to be vast. Also not yet fully assessed is the potential for producing other resources from the little-known geologic structures of our Continental Shelf.

The living resources of the sea are a valuable part of our domestic food supply and loom now as one important part of a program to feed the world's population, critically short of protein. A large portion of U.S. shellfish, salmon, and other marine food resources is dependent on the coastal zone habitat for part of its life cycle.

In view of these factors, the Nation has an important stake in the coastal zone and with this in mind the panel established its goal:

To achieve a quality of environment which will ensure enjoyment, economic development and sensible utilization of our resources.

To understand the problems confronting the coastal zone, the panel examined the activities relating to this environment.

Our nearshore waters and coastlines are subjected to often conflicting activities and from them stem physical changes, legal entanglements, and institutional competition, the major contributors to the regions' problems.

A single action may have relatively little impact on the Nation's shoreline. Over time, however, the result is that the resource base for certain uses is eroded. For example, private ownership and development has in many places severely reduced public access to beaches. The destruction of estuarine habitats by dredging and filling, acre by acre, ultimately can destroy a large part of U.S. fishing potential.

The pollution of estuarine and coastal waters by cities and industries, imperceptible at first, can and has reached conditions that destroy the areas' usefulness for fish and wildlife and recreation.

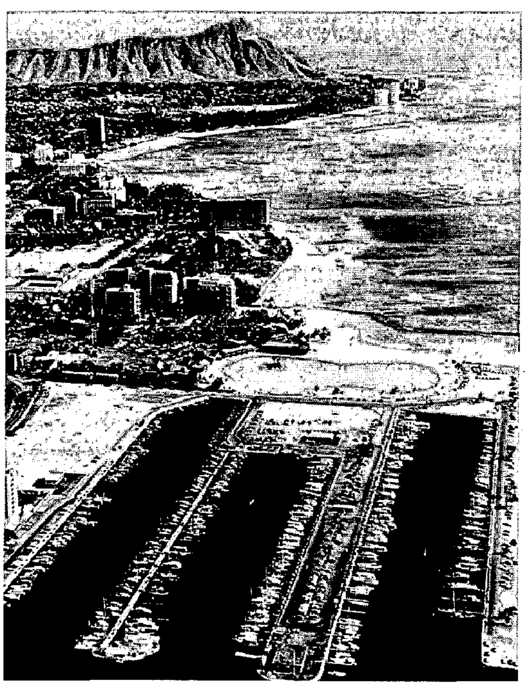

Figure 1. *Uses of the coastal zone vary greatly. The greatest pressure now comes from housing and recreation. (Federal Water Pollution Control Administration photo)*

The coastal zone is not a single resource, but an agglomeration of resources that includes the dry shore lands, marshes, the submerged lands, the overlying waters, and the plants and animals within.

Uses of the coastal zone described in the following pages are directly dependent on one or more of these shoreline resources. In addition, the various uses of estuaries are not independent; instead, they are essentially interdependent and thereby constitute multiple-use systems.

Specific uses are many and varied but have been generally classified as follows:

–Waste disposal (municipal sewerage, industrial wastes)

–Shoreline development (industrial, housing, ports, etc.)

–Exploitation of living resources (fisheries, aquaculture)

–Recreation (swimming, boating, sport fishing)

–Water resources (municipal and industrial supplies)

–Transportation (shipping, waterways, harbors)

–Wildlife and estuarine preservation

–Exploitation of non-living resources (oil, gas, gravel, etc.)

The following sections discuss each use in some detail. Presented are many facts and other data concerning man's activities in the coastal zone upon which the panel has based its conclusions. For additional discussion of many of these uses the reader is referred to appropriate reports of other panels.

I. URBAN AND COMMERCIAL DEVELOPMENT

Most major U.S. urban areas are situated on coastlines, bays, or the shores of the Great Lakes.

Several recent studies of urban waterfront areas have focused on current land use allocations (Tables 1-3).

Apparent in recent Seattle[1] and San Francisco Bay[2] Studies is the fact that most new waterfront commercial development is public-oriented (i.e., restaurants, motels, parking lots, etc.).

Many commercial developments (restaurants, motels and hotels, retail shops, and office buildings) can derive significant benefits from a location on the waterfront. With the exception of vacation-oriented activities, they usually are located in urban areas.

Waterfront uses in urban areas have generally been incompatible with most commercial uses. Manufacturing and distribution industries and terminal facilities, primarily located in the urban waterfront areas of cities, have tended to deter commercial development. Significant exceptions are urban renewal projects to redevelop old and abandoned port facilities such as in Baltimore and Philadelphia.

Table 1
SEATTLE HARBOR WATERFRONT LAND USE INVENTORY (1966)[1]

(thousands of square feet - Net Area)

Use	Area	Per cent
Residential	18	–
Commercial	9,321	19.8
Industry	10,711	22.9
Transportation[2]	13,814	29.5
Government and Institutional	4,624	9.9
Cultural and Recreational	58	–
Undeveloped and Misc.[3]	8,402	17.9
Total	46,948	100

Source: Records of the Puget Sound Regional Transportation Study.

[1]Shoreline Utilization in the Greater Seattle Area, study by Management & Economics Research Inc., January, 1968.

[2]One-fourth of this figure is for auto parking lots.

[3]One-third of this is reserved for facilities already under construction or planned (1967).

Table 2
BALTIMORE REGIONAL PORT SHORELINE LAND USE[1]

Use	Miles	Per cent
Residential	147	55
Industry	42	16
Government	13	5
Recreational	24	9
Unused	40	15
Total	266	100

Source: Chesapeake Bay Case Study, report by Trident Engineering Associates to the National Council on Marine Resources and Engineering Development, Sept. 28, 1967.

[1]The Baltimore Regional Port Shoreline is defined as the western coastline from the Chesapeake Bay Bridge to the Aberdeen Proving Grounds, a distance of 266 miles of water front.

II. INDUSTRIAL DEVELOPMENT

Use of coastal lands and waters for industrial development is an important part of the economic growth of any given area. Industry is expected to continue as a major competitor for use of a coastal environment. Problems associated with industrial development are:

–Pollution due to industrial wastes

–Space conflicts with other growing uses both on the nearshore and backshore accesses

–Loss of aesthetic attractions

Factors affecting waterfront location by industrial firms:

–*Transportation.* Either the raw materials or finished products processed or distributed by the firm require water transportation and additional costs would be incurred if a waterfront site were not obtained. This is the most obvious and compelling reason for such locations.

–*Water use.* Many industries use water in their manufacturing processes. Industrial use far exceeds household use. Only a small portion of the industrial water intake is actually consumed. Brackish (saline) water is satisfactory for many industrial purposes. Approximately 20 per cent of the water used by U.S. industries in 1965 was brackish (saline), and this percentage is rising each

[1]Shoreline Utilization in the Greater Seattle Area, study by Management & Economics Research Inc., January 1968.

[2]Report on Waterfront Industry prepared for San Francisco Bay Conservation and Development Commission, February 1968.

Table 3
SAN FRANCISCO BAY SHORELINE LAND USE[1]
JULY 1966

Use	Rank Order	Miles	Per cent Total	Per cent Occupied
Residential	2	36.97	10.7	20.3
Commercial	12	7.35	2.1	4.0
Services	15	1.61	0.5	0.9
Parking	16	0.11	–	–
Water-related industry[2]	5	19.05	5.5	10.5
Other industry	7	14.08	4.1	7.7
Utilities	11	7.87	2.3	4.3
Transportation[2]	4	34.28	9.9	18.8
Institutional[2]	9	13.07	3.8	7.2
Recreation	6	17.33	5.0	9.5
Marinas and related	14	1.75	0.5	1.0
Salt evaporators	10	9.88	2.9	5.4
Agriculture	8	13.57	3.9	7.4
Forestry and related	13	5.42	1.6	3.0
Subtotal Occupied		182.34	52.8	100.0
Marsh	1	126.95	36.8	
Vacant	3	35.97	10.4	
Total Miles Shoreline		345.26	100.0	

Source: Report on Waterfront Industry prepared for San Francisco Bay Conservation and Development Commission, February, 1968.
[1]Military use of the San Francisco shoreline for depots, maintenance centers, bases, and airfields totaled 31.81 miles, representing 17.4 per cent of the developed shoreline. These military measurements were distributed among water-related industry, transportation, and institutional uses.
[2]Includes river areas outside the Bay proper. The total mileage of Bay shore is approximately 276 miles.

year.[3] An abundant supply of such water is thus an attraction for many industries.

–*Waste disposal.* Disposal of wastes make a waterfront location an advantage but is often incompatible with other uses of the shoreline and water, and is under increasing pressure by pollution control authorities.

The deep-water urban regions have a special role in the National economy. U.S. dependence on foreign sources for oil, iron ore, and other primary metals makes deep-water sites for basic industry a National requirement. For example, all but two of the Nation's major steel mills are located at ports. (Exceptions are World War II Government-built plants located inland for reasons of security.) Now the absence of deep water ports to receive modern supercarriers[4] places U.S. steel mills at a disadvantage in world competition.

Increasing property taxes force most private land investors to dispose of their land as quickly as possible, which often involves subdividing or selling smaller portions. Local government units, anxious to increase the tax base, are not likely to preserve large and valuable shoreline parcels for an indeterminate future use. Suitable sites for heavy, water-oriented industry, important to the balanced economic growth of a region, thus are rapidly becoming scarce.

[3]1965 Census of Manufacturers, *Water Use in Manufacturing.*

[4]See Chapter 5 and Appendix C for data on port facilities.

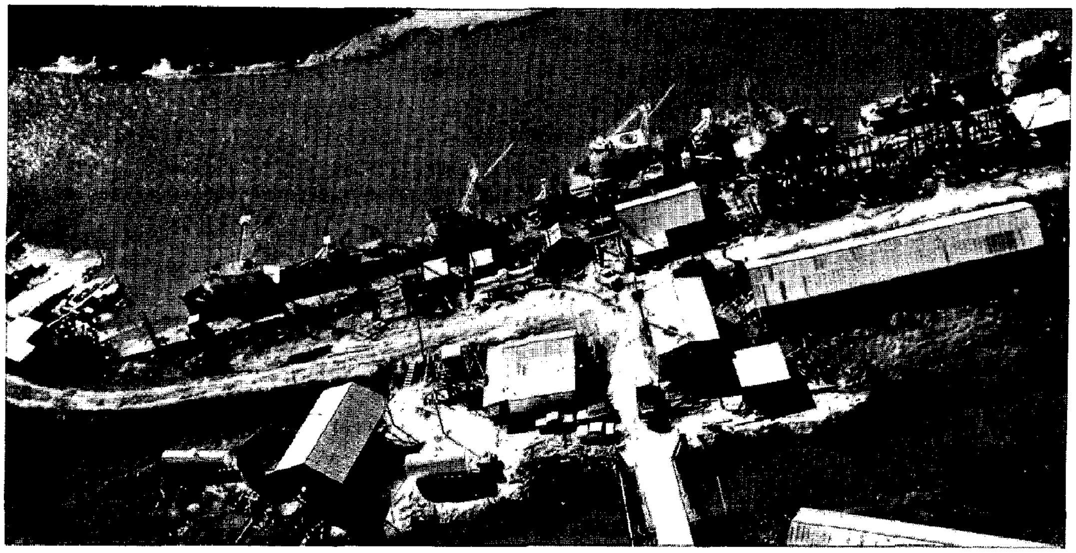

Figure 2. *Industrial use of the waterfront–a fish processing plant. (Bureau of Commercial Fisheries photo)*

It appears that recent pollution control legislation will reduce the advantages of waste disposal previously inherent in a waterfront location. In most cases, however, it is likely that industrial location decisions will not be significantly affected, since the industries concerned usually derive other benefits from a waterfront location.

It is within the technological and economic capability of the industries requiring waterfront sites to comply with regional standards for compatibility, i.e., not pollute the air or water, interfere with other public uses or despoil a shoreline's appearance.

These industries seek waterfront sites in metropolitan regions to achieve major savings in raw materials transport, processing, and product distribution, and their managements are aware that the costs of operating in metropolitan areas include pollution abatement equipment and well-maintained plants and grounds.

If remaining shoreline resources are to be adequately managed, it is important that additional information be obtained regarding the economic importance of waterfront location to various industries.

III. HOUSING DEVELOPMENT

Housing is a major factor affecting coastal zone development. Both demographic and socio-economic trends project a rapid increase of private waterfront development.

It seems probable that if current trends continue all wetlands will be filled and used for home building. Figure 3 shows the degree of development which has occurred in Boca Ciega Bay, Florida, between 1949 and 1965. In San Diego, a house sells for 40 per cent more if it is on the waterfront. Apartments in Columbus, Ohio, rent for 15 per cent more per month if they have a view of a 7½ acre "lake" which the builder salvaged from an abandoned sand pit. On Long Island, waterfront plots can command a premium of $5,000 to $15,000 over other lots.[5]

A survey in 1966 by the Fish and Wildlife Service indicated that commercial and private housing development (and related ventures) was the second principal cause in the loss of estuarine area. It is estimated that by 1975 housing developments will have become the leading cause.[6]

Furthermore, sewage from waterfront homes often seeps directly into nearby waters, adding to pollution.

IV. RECREATION–BEACHES AND PARKS

Competition for land and water is sharpest precisely where the need for water-based recreation is greatest–near metropolitan areas. The

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[5] National Home Builders Institute, Washington, D.C.

[6] Report of Bureau of Sport Fisheries and Wildlife to House Merchant Marine and Fisheries Committee, 90th Congress, March 6, 1967. See Table 1, Chapter 3.

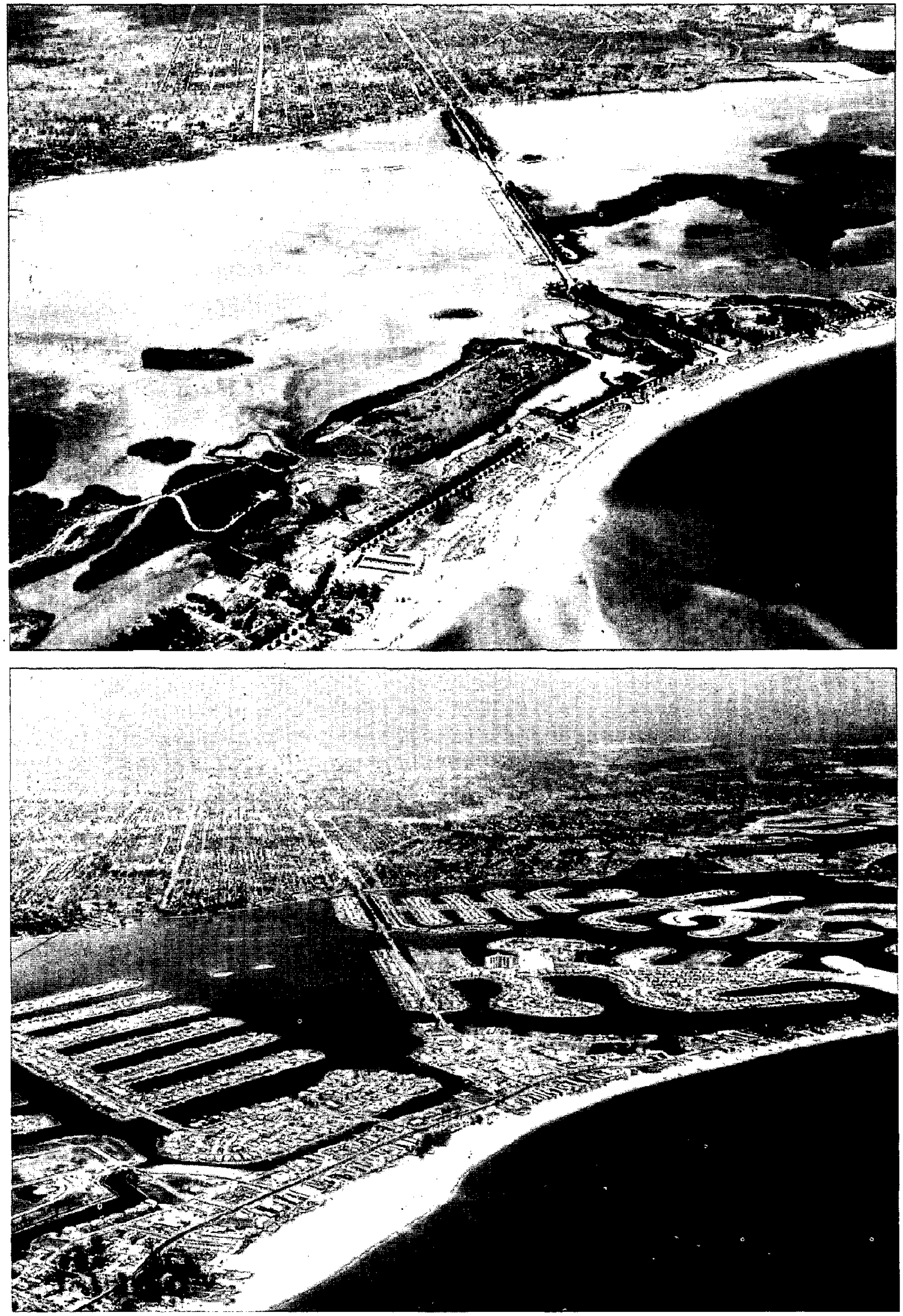

Figure 3. *Boca Ciega Bay near St. Petersburg, Florida, showing land development for housing. The upper photograph shows the Bay in 1949. The lower photograph shows the same area in 1965. Ecologists claim that excessive development can destroy the biological productivity of an estuary. (Bureau of Commercial Fisheries photo by Airflite, St. Petersburg)*

problem involves not so much the water's physical amount as its quality and accessibility.

Outdoor recreational facilities are most urgently needed near metropolitan areas. As a result of continued urbanization, three-quarters of the U.S. population will live in these areas by the turn of the century, and they will have the greatest requirement for outdoor recreation.

Table 4

REGIONAL SHORELINE ALLOCATION

Shoreline location	Detailed shoreline (statute miles)	Recreation shoreline (statute miles)	Public recreation shoreline (statute miles)
Atlantic Ocean.....	28,377	9,961	336
Gulf of Mexico....	17,437	4,319	121
Pacific Ocean.....	7,863	3,175	296
Great Lakes.....	5,480	4,269	456
U.S. total..	59,157	21,724	1,209

The competition for land use poses both a challenge and an opportunity for those metropolitan areas situated near the coasts and the Great Lakes. Although such areas may not be able to reserve facilities for the complete range of water-associated recreational activities, the potential to secure some is shared by all.

Population pressures on public and outdoor recreation facilities are exceeding previous expectations by wide margins. A 1965 survey conducted by the Bureau of Outdoor Recreation,[7] indicated that visits to beaches and seashores in 1980 would total nearly 10 billion, more than double the same estimate made in 1960. Projected visits in the year 2000 would be nearly 17 billion, four times the 1960 estimate.

Based on the 1965 survey the most popular summertime activities ranked in order are: walking for pleasure, swimming, driving for pleasure, playing outdoor sports, bicycling, sightseeing, picnicking, fishing, attending outdoor sports events, boating, nature walks, and camping. Projections for the year 2000 indicate some changes in ranking with the following the top eight activities: swimming, playing outdoor sports, walking for pleasure, driving for pleasure, sightseeing, picnicking, and boating.

The present shoreline given to recreation is shown in Tables 4 and 5.[8] At present about 6½ per cent of the total recreational shoreline is in public ownership. To meet demands it is considered essential that about 15 per cent be available for public use.[9]

Private enterprise plays an important role in outdoor recreation in coastal areas, a role not always recognized. The enormous private investments in such resort cities as Atlantic City, Miami Beach, and their numerous but smaller counterparts provide services and facilities for people seeking a variety of outdoor recreation experience ranging from big-game fishing to lounging on the patio of a luxury hotel with a seascape as background.

The technical relationships between recreation and other uses are complex. Partially treated domestic sewage may render water unfit for swimming or drinking but may act as a fertilizer for fish production. Some recreational uses are incompatible with others, e.g., water skiing and fishing. What share of the salmon supply should be allocated for food and what for recreation? Rarely will the answer be all or none; more likely it will be a rational balance of values. On the other hand, certain rare environments like the Indiana dunes must be reserved intact or lost completely.

Perhaps more than in any other coastal application new concepts of engineering and technology can assist or join with other uses. For example, large new offshore port complexes also could serve as public recreational sites. Shorelines can be lengthened by dredging new harbors and spoil can be used to create islands and peninsulas.

V. RECREATION—BOATING

Boats in the United States total about 8.3 million, about 80 per cent of which are located in

[7]Department of the Interior, *Outdoor Recreation Trends,* April 1967.

[8]*Shoreline Recreation Resources of the United States,* Outdoor Recreation Resources Review Commission Report No. 4, 1962.

[9]*Our Vanishing Shoreline,* 1966.

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Table 5
ESTIMATED MILEAGE, BY STATE, OF THE U.S. RECREATION SHORELINE, BY TYPE, OWNERSHIP, AND DEVELOPMENT STATUS

State	Total (miles)	Type			Ownership			Development status
		Beach (miles)	Bluff (miles)	Marsh (miles)	Public: Recreation areas (miles)	Public: Restricted areas (miles)	Privately owned (miles)	
Alabama	204	115	....	89	3	1	200	Low.
California	1,272	283	883	106	149	100	1,023	Moderate.
Connecticut	162	72	61	29	9	....	153	High.
Delaware	97	41	....	56	9	9	79	Moderate.
Florida	2,655	1,078	406	1,171	161	122	2,372	Low-mod.
Georgia	385	92	....	293	5	....	380	Moderate.
Illinois	45	13	32	....	24	4	17	High.
Indiana	33	33	....	....	3	....	30	Do.
Louisiana	1,076	257	....	819	2	....	1,074	Low.
Maine	2,612	23	2,520	69	34	....	2,573	Do.
Maryland	1,368	40	912	416	3	113	1,252	Do.
Massachusetts	649	240	288	121	12	6	631	High.
Michigan	2,469	292	1,959	218	357	....	2,112	Low.
Minnesota	264	22	175	67	19	....	245	Do.
Mississippi	203	134	....	69	....	25	178	High.
New Hampshire	25	7	9	9	3	....	22	Very high.
New Jersey	366	101	33	232	18	15	333	Do.
New York	1,071	231	590	250	47	....	1,024	Moderate.
North Carolina	1,326	285	260	781	139	42	1,145	Low.
Ohio	275	20	195	60	9	5	261	High.
Oregon	332	133	181	18	101	....	231	Moderate.
Pennsylvania	57	9	44	4	19	....	38	Do.
Rhode Island	183	39	145	4	8	10	170	High.
South Carolina	522	162	....	360	9	10	503	Moderate.
Texas	1,081	301	421	359	5	18	1,053	Very low.
Virginia	692	160	118	414	2	26	664	Low.
Washington	1,571	121	1,294	156	46	27	1,498	Moderate.
Wisconsin	724	46	634	44	13	48	663	Do.
Total	21,724	4,350	11,160	6,214	1,209	581	19,934	......

the 30 coastal and Great Lakes States.[10] Projections indicate that the number of boating participants will more than double by the year 2000.[11]

Safety is the greatest concern in recreational boating. The annual number of major boating accidents has increased 34 per cent in the last five years.[12] In 1967 over 4,000 accidents involving 1,312 deaths were reported by the Coast Guard.[13]

[10] *Boating Industry Magazine,* National Industrial Association-National Association of Boat and Engine Manufacturers, January 1968. The number of boats actually registered in 1967 was 4,458, 893. See Appendix B.

[11] *Ibid.*

[12] *Boating Statistics 1967,* CG-357.

[13] *Ibid.*

Presently boating regulations are administered as follows:

–Federal Motorboat Act of 1940 which sets basic boat classes and equipment safety standards[14]

–Federal Boating Act 1958 which permits certain State regulation and control[15]

–Specific State watercraft regulations which do not require uniformity or national guidelines.

[14] Act of April 25, 1940, as amended, 54 Stat. 163, 46 U.S.C. 526-526t.

[15] Act of September 2, 1958, as amended, 72 Stat. 1754, 46 U.S.C. 526l,o,u, 527-527h.

Figure 4. *Recreational boating and public access to the water are a major concern in future use of the coastal zone. (Coast Guard photo)*

A summary of the number of boats presently registered by States, along with a brief statement of State numbering requirements, is shown in Appendix B.

A review of boating accident statistics indicates that improved boating safety is perhaps a matter of sound education and not regulatory licensing.[16]

The Coast Guard has proposed legislation to:[17]

–Establish safety standards applicable to the manufacture of recreational boats and associated equipment and regulate as necessary items of equipment carried on recreational boats

–Approve State boating safety programs designed to reduce boating accidents if they comply with certain Federal requirements

–Make grants-in-aid to the States to assist in carrying out their boating safety programs.

VI. SPORT FISHING AND HUNTING

Sport fishing and hunting, both important in coastal areas, are increasing at a rate faster than National population growth. Estimates place the number of serious salt water sports fishermen at 8.3 million. An additional three million participate to a lesser extent and on the Great Lakes.[18] In 1966, 97 million man-days and an estimated $800 million were spent on the sport.[19] By the year 2000, the number of anglers is expected to triple.[20] If trends continue, salt water angling will represent about one-third of the National sport fishing effort.

The Department of Interior's Bureau of Sport Fisheries and Wildlife estimates that there are about 11 million persons who do not hunt or fish,

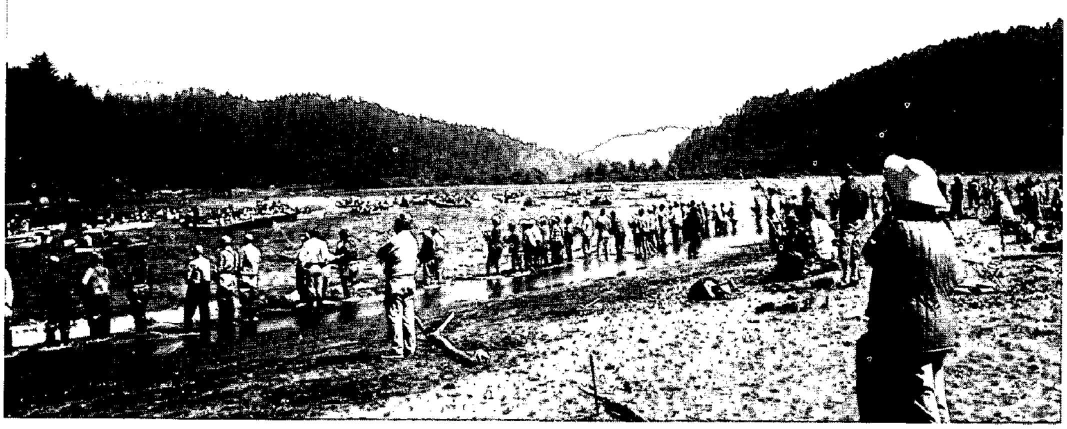

Figure 5. *There are over 8 million sports fishermen who constitute an important use of the coastal zone. (Bureau of Outdoor Recreation photo)*

[16] Statement of Rear Admiral W. L. Morrison, U.S.C.G., Assistant Chief of Staff for Boating Safety, U.S. Coast Guard, to Special Studies Subcommittee of the Committee on Government Operations, July 1, 1968.

[17] H. R. 15223 and S. 3015 of the 90th Congress, entitled Recreation Boat Safety Act.

[18] *Progress in Sport Fishery Research,* Department of the Interior, Bureau of Sport Fisheries and Wildlife Resource Publication 39, April 1967.

[19] *Ibid.*

[20] *Estuarine Programs,* Bureau of Sport Fisheries and Wildlife report, January 1967.

but pursue birdwatching, wildlife photography, and other forms of nature study.[21]

Many frequent coastal areas because of the abundance and variety of life there. By 2000, this group is expected to exceed 40 million.

All marsh species, shore birds, and the miscellaneous fish-eaters have a function in coastal ecology, and their presence gives added pleasure to millions of visitors.

North America is endowed with many species of birds whose natural habitat is in or near the water. Waterfowl were hunted in 1967 by nearly two million individuals, who spent over $87 million on this sport.[22]

A principal role in sport fishery and wildlife management is played by the National Wildlife Refuge System. Activities include planning and execution of a balanced wildlife management program for migratory waterfowl, upland wildlife, and other forms of wildlife on these areas; the preservation of rare and endangered species; soil and water conservation; and compatible outdoor recreation.

Of the 312 units in the Refuge System, 78 are coastal installations[23] with a combined shoreline of more than 500 miles and an area of more than 18 million acres, of which 682,000 are estuarine.

Figure 6. *Great concern for the wildlife and its environment is shared by the dramatic voice of the amateur naturalist. (National Park Service photo)*

Twenty-four States operate coastal waterfowl preserves with funds provided under the Pittman Robertson Act.[24] The more recent Dingell-Johnson Act[25] is not being significantly utilized for the preservation of estuarine and marine areas primarily because matching funds are unavailable. Most State fish and game departments operate on license revenues. Licenses are not required for fishing in many coastal areas and this creates reluctance to spend license revenue on marine projects.

This gap is especially acute in the South Atlantic and Gulf of Mexico. These Acts authorize the appropriation of funds collected from Federal excise taxes on sporting arms and ammunition and on sport fishing tackle. The funds, apportioned as matching grants to the respective States, are used to study problems of fish and wildlife restoration and management; to purchase, develop, manage and administer lands and waters; to restore natural habitat; and to maintain completed projects.

Many National Wildlife Refuges are superimposed upon such other Federal projects as water resource and reclamation works. Close coordination is required between agencies to insure that lands are managed to the best interest of wildlife consistent with the primary purpose of the project. Joint use is possible with proper planning. The combined Assateague Island National Seashore and Wildlife Preserve instituted by the Department of Interior in 1968 is an excellent example of effective joint use.

VII. COMMERCIAL FISHING

The 1967 U.S. commercial fishing catch at dockside was approximately four billion pounds valued at $438 million.[26] Of this catch some 70 per cent worth $300 million was caught in the U.S. coastal zone.[27] Of the total, 24 per cent by

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[21] Information furnished by the Bureau of Sport Fisheries and Wildlife.

[22] Bureau of Sport Fisheries and Wildlife, *National Survey of Fishing and Hunting,* 1968.

[23] The locations are shown in Fig. 4, Chapter 7. See also the description of the activities of the Bureau of Sport Fisheries and Wildlife in that chapter.

[24] Act of September 2, 1937, as amended, 50 Stat. 917, 16 U.S.C. 669-669l.

[25] Federal Fish Restoration and Management Projects Act, Act of August 9, 1950, as amended, 64 Stat. 430, 16 U.S.C. 777-777k.

[26] *Fisheries of the United States-1967,* Bureau of Commercial Fisheries Publication CFS-4700, April 1968.

[27] *Ibid.*

dollar value was shrimp.[28] U.S. coastal waters have an estimated annual sustainable total fish yield of 30 billion pounds.[29]

Coastal and estuarine waters and marshlands are vital to the nutrients and life support of about two thirds of the entire marine fisheries harvest. Seven of the 10 most valuable species in our commercial fisheries spend all or important portions of their life cycle in estuarine waters and at least 80 other commercially important species are dependent on estuarine areas.

The fisheries in the estuarine zone are characterized by their diversity. As in all cases where political boundaries are superimposed on natural systems, systems of laws and regulations have developed in many States that impede wise resource exploitation or preclude truly adequate conservation. Many species of fish have either life ranges or migratory and distribution patterns that cross the artificial political boundaries.

A few examples illustrate some of the problems. Many States have laws established either upon unsupported assumptions or to accommodate a particular interest group, often the sport fisherman, at the expense of the commercial fisherman.

For instance, in Maine it is prohibited to take tuna other than with a harpoon or hook and line. No rational purpose seems to exist for this prohibition and the use of appropriate equipment conceivably could double the tuna catch while both maintaining the tuna stock and preserving sport fishing.

In Connecticut, "Blue Laws" prohibit commercial fishing for smelt, tomcod, shad, alewives, and glut herring from Friday sunset to Monday sunrise. This measure seriously inhibits commercial fishery development.

In Alaska, certain types of vessels and fishing gear are excluded in taking salmon, shrimp, and clams without a clearly established scientific or conservation basis. If the mentioned resources are to be exploited consistent with efficiency and maximum sustained yield these regulations should be modified.

Such provisions have the overall effect of depressing the commercial fishery resource to the detriment of the State, industry, and wise conservation. It is probable that the near-shore fishery could double without depletion if certain measures including adequate regulatory provisions were adopted.

A legal framework relating to the coastal waters should be established sufficiently uniform to accommodate the continuous natural system it seeks to regulate. The basic objective of State laws and regulations should be a healthy commercial and sport fishery consistent with multiple or shared use, economic efficiency, and maximum sustainable yield.

These objectives should be attained on a regional basis or on a National scale through greater uniformity in State laws and regulations which are species-oriented, non-discriminatory, rooted in scientific knowledge, and motivated by the desire to exploit living resources to the fullest extent possible consistent with efficiency and maximum sustainable yield. Certain local peculiarities would necessitate variations, but laws and regulations among the States must be interrelated.[30]

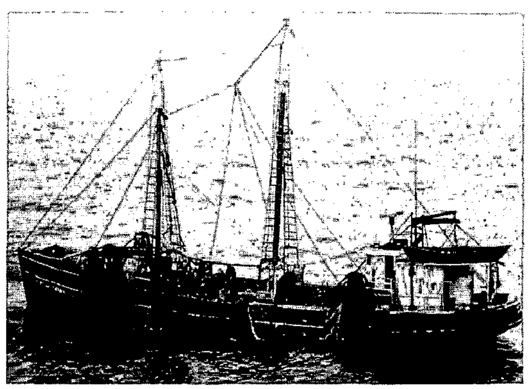

Figure 7. *The role of the fishing industry is often hampered by obsolete equipment and conflicting laws. (Coast Guard photo)*

Next to economics and legal problems, the fishing industry is concerned over the encroachment of the petroleum industry on what heretofore have been exclusive fishing grounds. Recent

[28] *Ibid.*

[29] Report of the Panel on Fishing at the Second Conference on the Continental Shelf, National Security Industrial Association-Ocean Science & Technology Advisory Committee (OSTAC), November 1967.

[30] Fisheries problems are discussed in greater detail and specific recommendations are contained in the Report of the Resources Panel of the Commission on Marine Science, Engineering and Resources.

activity off New England and in Lake Erie has caused particular worry.

The New England Fisheries & Conservation Committee[31] has expressed alarm that oil exploration on Georges Banks imperils a resource that is a vital industry to New England and "constitutes 12 per cent of the world's fish supply." There is concern that an accident similar to the oil well blowout at Cook Inlet, Alaska, might cause pollution ruinous to New England commercial fisheries, sport fishing and the recreation industry.

Conflicts presently exist between the shrimp and oyster fisheries and the oil industry along the Gulf Coast, particularly in Louisiana. In a report to the panel,[32] Dr. Lyle S. St. Amant, Assistant Director, Louisiana Wildlife and Fisheries Commission, stated:

The growing of oysters and the harvesting of shrimp in Louisiana is a big business--but it is only a small fraction as big as the petroleum industry in the state. In 1966, according to the Independent Petroleum Association of America, the value of crude oil, natural gas liquids and natural gas, at the well in Louisiana was approximately $3,194,341,000 and the petroleum industry paid 46 per cent of the State's revenue.

The value of Louisiana fisheries in 1966 was approximately $100 million.

Because of the high productivity of both the mineral and seafood industries, it is apparent that every reasonable effort must be made to allow the two industries to operate in the same area without serious conflict.

The Federal Government, State and local governments, National conservation organizations, and private citizens have expressed grave concern in recent years over the increasing destruction of estuaries providing critical habitat for a major portion of the marine, sport and commercial fisheries, waterfowl and other wildlife resources of the Nation.[33] Reflecting this concern, the National Estuarine Study of the Department of the Interior[34] will attempt to identify endangered areas critical to wildlife preservation.

VIII. AQUACULTURE

Aquaculture today is of minor importance although in the future it could increase dramatically our domestic fish production. Depending on market demands and research and technology, aquaculture can be expected to reach significant proportions in 20 to 30 years.[35]

Systematic production of both finfish and shellfish could reduce present demand for offshore water and bottom space but also could stimulate further demand for marsh lands and shallow estuarine waters.

Aquaculture is employed widely in Asiatic countries: 5 per cent of Japan's total fish catch comes from coastal areas with retention devices. China, Taiwan, the Philippines all report considerable "pondfish" production.[36]

Excluding leased shellfish beds, marine aquaculture activity in the United States is limited to developmental and pilot studies. However, thriving freshwater commercial trout and catfish "farms" have developed recently; production can be increased tremendously if markets are available. For example, it is estimated that in a five-State south central region about 13 million acres are suitable for conversion to catfish ponds.[37]

Aquaculture is attractive because it offers relief from the greatest handicap of the fishing industry–reliance on an uncertain common property resource. Because a fish farmer has full control of

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[31]Report of meeting of New England Fisheries & Conservation Committee, Nov. 10, 1967.

[32]Presented at panel hearings, Houston, Jan. 24, 1968.

[33]See Chapter 3 for a more detailed discussion on losses in wildlife and nutrient areas.

[34]Public Law 90-454 of the 90th Congress, Aug. 3, 1968, (formerly H.R. 25) authorizes the Secretary of the Interior, in cooperation with the States to conduct an inventory and study of the Nation's estuaries and their natural resources. An additional study authorized by Section 5(g) of the Clean Water Restoration Act of 1966, Act of November 3, 1966, 80 Stat. 1246, 33 U.S.C. 431, various sections, is being conducted by the Federal Water Pollution Control Authority. See Chapter 9.

[35]Report of the Panel on Fishing at the Second Conference on the Continental Shelf, National Security Industrial Association-Ocean Science & Technology Advisory Committee (OSTAC), November 1967.

[36]Ryther and Bardach, *The Status and Potential of Aquaculture,* report to the National Council on Marine Resources and Engineering Development by the American Institute of Biolgoical Sciences, Publication PB 177 768 of the Clearinghouse for Federal Scientific and Technical Information, 1968.

[37]Report of Department of Interior at panel hearing, Oct. 10, 1967.

Figure 8. *Aquaculture (portrayed here is an artist's conception) is attractive because it offers relief from the handicap of reliance on an uncertain common property resource. (Bureau of Commercial Fisheries photo)*

the resource and harvest it is to his advantage to improve his technology and management procedures. Farming of shrimp, other crustaceans, fish, and especially mollusks is possible at the edges of the sea. It is even possible to envision aquaculture operations sharing controlled water resources, transportation, and space allocations with other industries. For example, plans are being made to use the waste heat from a power plant to warm the water of an oyster farm on Long Island.

IX. MARINE PETROLEUM EXPLOITATION

The petroleum industry is the largest commercial enterprise exploiting subsea mineral reserves. The number of offshore oil, gas, and sulfur facilities has increased dramatically in the past 10 years. Figure 10 shows the number of new oil wells drilled each year in U.S. coastal waters. The total presently existing is in excess of 16,000.

Oil and gas exploitation locations are shown on Figure 11. Of particular significance is new activity beginning off Alaska, the New England Coast, and in Lake Erie.

Current offshore oil production technology is applied primarily to the design and installation of fixed structures with platforms elevated above the water. The largest of these, installed during 1968 in the Gulf of Mexico in 340 feet of water, involves a total tower height of nearly 500 feet. Designs for water depth of 600 feet are under consideration. Similarly, structural towers with the platform and equipment submerged to diver depth are in design stages.

Divers utilized by the oil industry are constantly extending the limits of diving capability. Saturated techniques with diver lockout and decompression chambers have been developed. Recent tests of divers performing functional tasks on a simulated wellhead in 600 feet of water

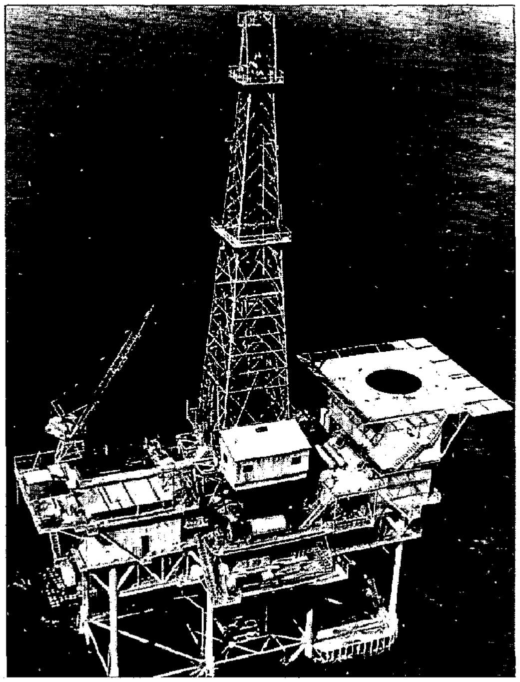


Figure 9. *There are more than 12,000 offshore oil wells off the U.S. coasts. Along with transportation and fishing, this industry now constitutes a major use of the Continental Shelf. (Shell Oil Co. photo)*

demonstrated man's ability to perform useful work in such depths.

Many problems faced by the petroleum industry are common to other users of coastal waters and their resolution is in the best interest of all. These include:[38]

–Improved navigation. The oil industry believes there is a pressing need for improved navigation systems. Accuracies in the order of ± 50 feet up to 200 miles from shore are indicated.

–Environmental forecasts. Better understanding and predictions of wind, sea, storms and other environmental data is needed to effectively plan and utilize personnel and materials.

–Traffic control in congested waters. This is important for the safety of oil rigs as well as the vessels transiting or operating in congested areas.

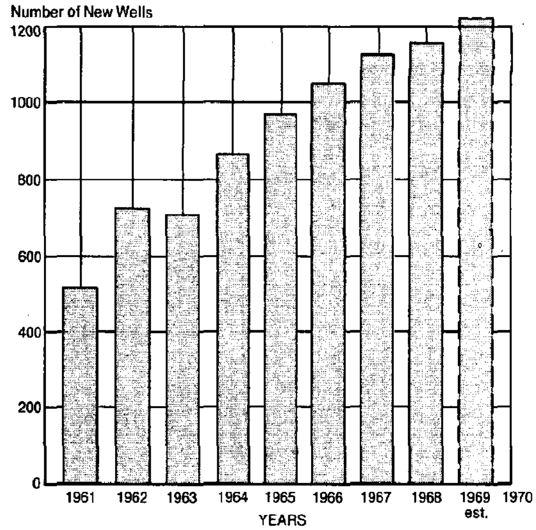


Figure 10. *Number of new oil wells drilled off the U.S. coast 1960-1970. (Source: American Petroleum Institute)*

–Surveys. Bathymetric and reconnaissance mapping of coastal waters is an effective means to reduce user spatial and time demands as well as improve the effectiveness of user operations.

–Jurisdictions. It is in the interest of all users of coastal spaces to determine Federal-State jurisdiction, and resolve unclear or nonuniform regulatory procedures.

X. MARINE MINING

Marine mining, although under a great deal of study and exploration, is not increasing substan-

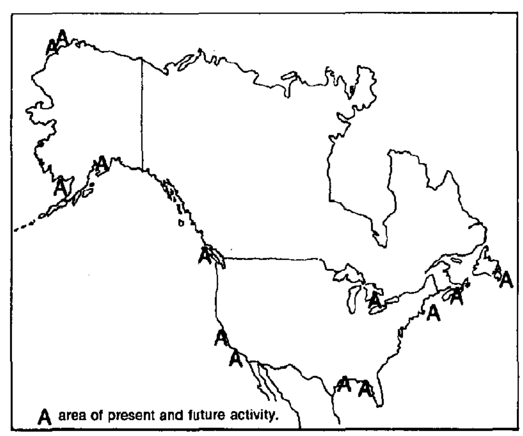


Figure 11. *Offshore oil and gas exploitation activity. (Source:* Offshore Magazine, *June 1968)*

[38]These problems were identified by the Panel on Petroleum at the Second Conference on the Continental Shelf, National Security Industrial Association-Ocean Science & Technology Advisory Committee (OSTAC), November 1967.

tially at this time and projections are that with the exception of sand and gravel it is not likely to do so in the near future. Chief industries at this time are:

–Sand and gravel. Production of sand and gravel from marine deposits is not reported separately by the U.S. Bureau of Mines, but is estimated at roughly $15 million annually.

Plentiful deposits are available on land and can be worked with a small investment, but the cost of transportation is a large part of the selling price, and the product is used mostly in urban centers. With the growth of our cities, and the zoning out of nearby gravel pits, the shorter haul with cheaper sea transportation from offshore sources make them increasingly attractive and it can be expected that growth of this industry will accelerate.

–Oyster shell. Production remains approximately constant at an estimated $30 million annually. The product is used for aggregate in concrete and road material in the manufacture of portland cement and lime, and for poultry grit and fertilizer additives. Although ample deposits exist, those nearer the market are gradually being depleted, and the increased transportation costs in working more distant deposits will raise the market price. Total production is not expected to increase substantially.

–Other minerals. Only very limited sampling operations have been conducted for other minerals and there is no production as yet.

Phosphorite deposits of considerable extent have been explored along the southern California coast and the coasts of North Carolina, Georgia, and Florida, but it does not appear that they can be mined profitably in competition with amply available sources on land.

–Heavy metals. Gold, tin, and platinum have not been produced from the U.S. shelf except for minor amounts during sampling operations. During 1966 two U.S. companies undertaking offshore gold-bearing placer exploration in Alaskan waters decided to discontinue their efforts, but a third was sufficiently encouraged by results of its 1966 pilot production to resume in 1967.

The marine mining industry faces the same problems described in the preceding section. In some instances such as oyster shell dredging in Texas the conflicts with neighboring fishing industries are severe. In Maryland, however, where management is under a single State agency, oyster shell dredging is regulated and conducted without conflict.

XI. NAVIGATION AND SPATIAL CONFLICTS

Ship collision is neither a new problem nor is the frequency projected to increase. On the contrary, although ship tonnage is predicted to increase, the actual number of ships may decrease and improved safety equipment should result in fewer collisions. A significant consideration, however, is the increasing size of ships. Further, because of the exotic and often hazardous nature of the cargoes, the consequences of a collision or grounding become increasingly serious.

High traffic density occurs:

–Where ships alter course to round a headland and are likely to keep the same distance offshore.

–Where traffic is confined to a narrow strait, e.g., the Strait of Florida, through which pass about 150 ships per day.

–In the approaches to large ports, e.g., New York, where about 70 large ships per day enter or depart.

A more recent navigational problem has resulted from offshore oil installations, the outstanding example being the Gulf of Mexico. Here there are about 6,000 oil or other platforms offshore, with about half in or near shipping lanes. The daily deep draft traffic out of Gulf ports is over 300 vessels, and over 50 collisions have occurred since 1960 between ships and structures. Pipelines present added problems to fisheries and anchorages.

Installations may be outside shipping lanes and still cause interference with navigation. Off the Port of Galveston, a ship lost 37 hours anchored in fog because its radar could not differentiate between the sea buoys leading into the port and nearby oil installations. Off New Orleans ships have had difficulty in locating by radar the key sea buoy marking the channel entrance because it was hidden by an oil installation.[39]

[39] W. L. Griffin, Accommodation of Conflicting Uses of Ocean Space with Special Reference to Navigation Safety Lanes, Second Annual Law of the Sea Institute, University of Rhode Island, June 1967.

The foregoing "spatial conflict" situations contain a distinction relevant to the accommodation problem: traffic density involves conflict between like users of the same ocean space for the same type of use. The shipping and shelf installation problem involves conflict between different types of users of the same ocean space.

A solution to spatial conflict is to designate sea lanes. The idea of marine traffic lanes is over a century old, but as yet has only limited adoption. The current North Atlantic Track Agreement involves only 16 shipping companies flying six different flags. The use of these lanes by the *Andrea Doria* and the *Stockholm* undoubtedly would have prevented their collision.

Separate upbound and downbound courses for ships belonging to the Lake Carriers Association were adopted for Lakes Superior and Huron in 1911 and have since been extended to Lake Michigan (1926), Lake Erie (1947), and Lake Ontario (1949). These lanes have proved very effective.

Presently, sea lanes constitute two categories: traffic separation lanes for vessels and fairways through Continental Shelf installations.

Separation lanes established by the Coast Guard consist of two-way shipping lanes leading to harbor entrances, with inward and outward traffic separated by a safety buffer zone similar to the dividing strip on highways.

Fairways through Continental Shelf installations make use of the Corps of Engineers authority under the Outer Continental Shelf Lands Act (1953) to grant permits for offshore structures. Fairways are sea lanes that the Corps, after consultation with the shipping and oil industry, has agreed to keep free of fixed oil or other installations. Such fairways are not mandatory and may be changed. They presently exist only in the Gulf and while providing a partial solution to the problem of cargo carriers attempting to reach port, they do not solve the fishermen's difficulties.

Structural standards for offshore platforms have been self-imposed by industry. Experience gained in recent hurricanes indicates that the predicted severity of conditions was less than actually encountered, and many underdesigned structures failed. Their dismembered portions litter a considerable area of the seabed.

Although industry is obligated to remove such wreckage located on drilling sites, debris that has settled elsewhere remains. The larger pieces are menaces to surface navigation and vessels have been damaged or sunk by them. At the least, they

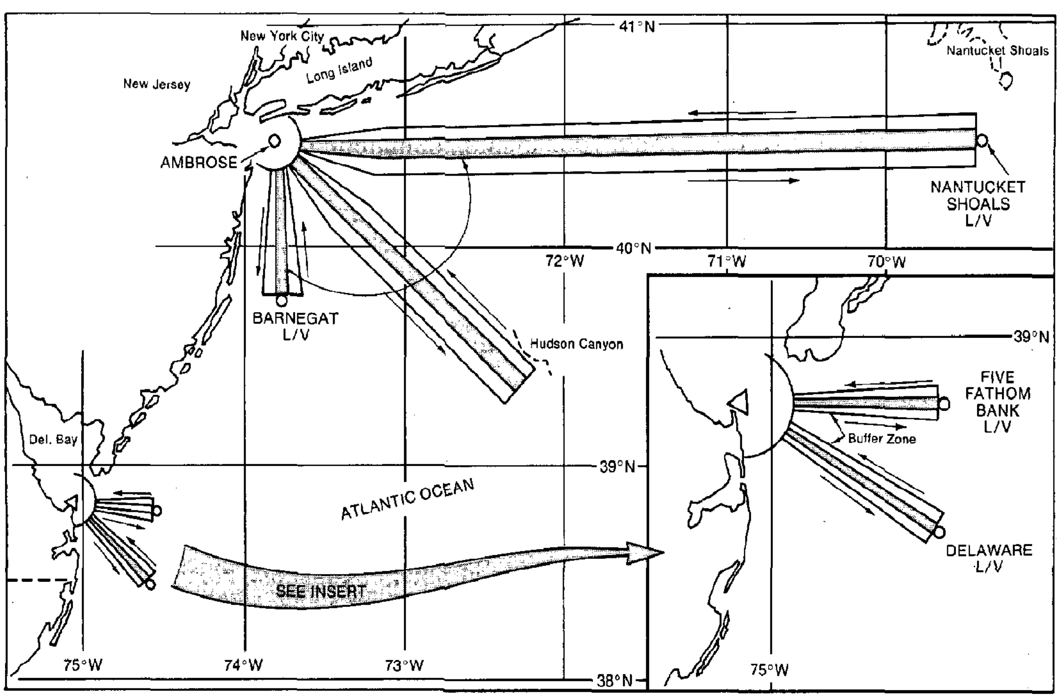


Figure 12. *U.S. Coast Guard sea lanes for vessel traffic control.*

impede trawling, and since the shrimp fishery on the Gulf Continental Shelf is the country's largest, the matter is of great concern.

Wrecks, in the ordinary sense of sunken vessels, are an increasing problem. Extant wreck legislation deals only with territorial waters, and admiralty law concerning wrecks beyond territorial waters is sparse. The size of mobile drilling platforms is such that the wreck of one of these can be a hazard even in 100 fathoms. The Corps of Engineers has no authority to remove wrecks on the Continental Shelf beyond territorial waters and since some of these contrivances are considered vessels, no present legislation applies.

Pipelines on the shelf in the Gulf of Mexico had a total length of over 1,800 miles in 1968, and more are being laid. Pipelines no longer utilized usually are abandoned and are not noted on nautical charts. The majority of pipeline casualties occurs as the result of storms. Ships' anchors can break them even if buried 10 to 20 feet beneath the seabed.

Although most new problems are related to the petroleum, gas, and sulfur industries, it can be anticipated that experimental and exploratory devices not connected with these industries will also present difficulties when developed. Submarine data collection installations, manned and unmanned, paralleling present weather and seismic data collection stations can be expected. Underwater recreational activities will increase. Each will tend to complicate matters further.

Federal jurisdiction with regard to such matters as navigation safety, obstruction control, naviga-

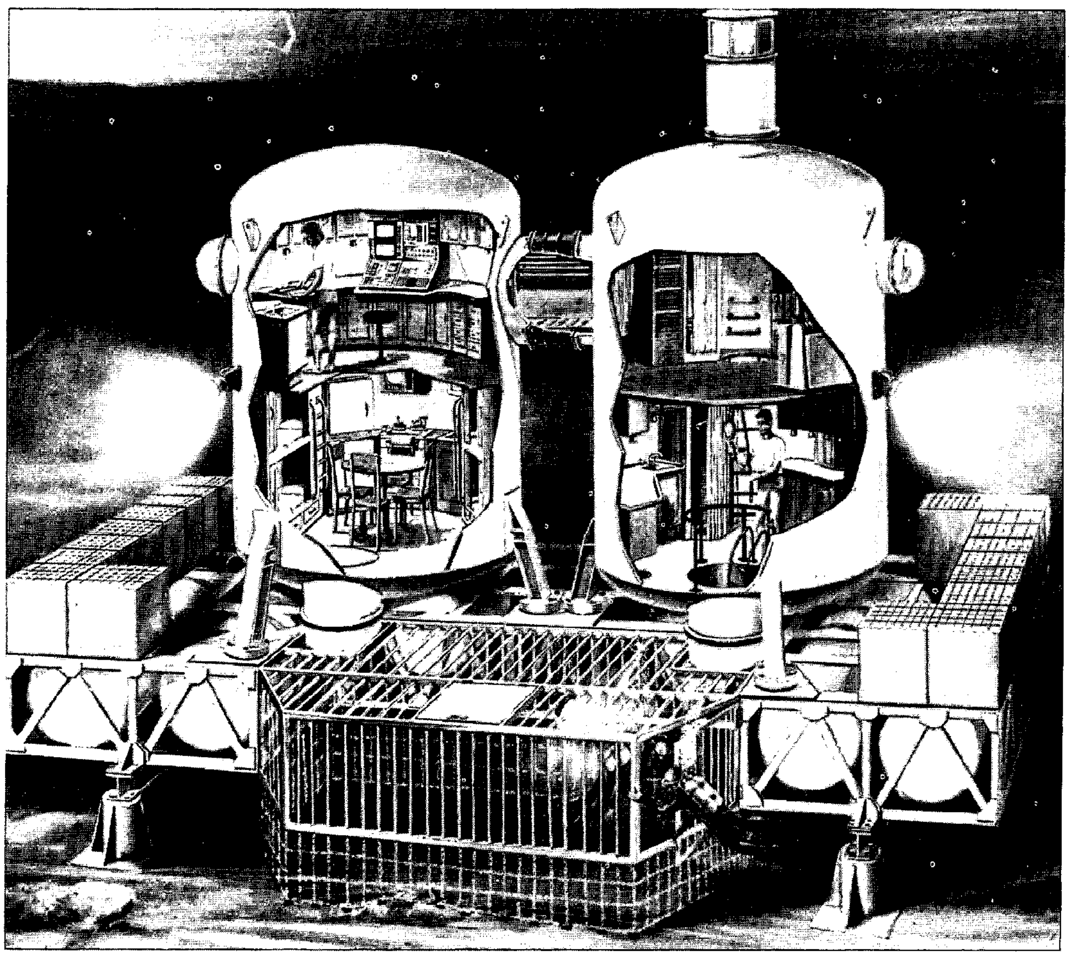


Figure 13. *TEKTITE I undersea habitat to be established in 1969. Such new activities must be included in the management and safety concerns for coastal waters. (U.S. Navy photo courtesy General Electric Co.)*

tional markings, etc., exists by virtue of one set of statutes for U.S. territorial waters, and for the Outer Continental Shelf via the Outer Continental Shelf Lands Act.[40]

Many matters not directly provided for by this statute have been covered by terms of lease or construction permits. For example, unused or damaged structures are required to be removed from the site. However, items not located on the lease/permit site, or not "fixed structures or artificial islands" such as vessels or mobile drilling units not engaged in drilling, do not come within the purview of these provisions.

The Convention on the Continental Shelf, Article 5(1) states:

The exploration of the continental shelf and the exploitation of its natural resources must not result in any unjustifiable interference with navigation, fishing or the conservation of the living resources of the sea.[41]

This is one of the first major actions to relate the competition of interest. However, no agency presently appears to have the authority to enforce this provision.

[40] Act of August 7, 1953, 67 Stat. 462, 43 U.S.C. 1331-1343; *United States* v. *Texas*, 363 U.S. 1 (1960); *United States* v. *Florida et al*, 363 U.S. 121 (1960). By the 1960 Supreme Court decisions in the United States–Texas-Florida litigation–the Outer Continental Shelf commences three marine leagues (nine miles) off the Gulf Coast of these States. Since territorial waters extend only to three miles, there exists off these States a belt six miles wide in which no clearcut jurisdiction exists over navigational matters.

[41] 15 U.S.C. 471 (1964).

Despite natural changes, both long term and catacylsmic, the more serious disturbances to the coastal environment that we have to consider are those caused by man. Man's uses–and abuses–of the Nation's shoreline outlined in Chapter 2 are producing changes in our environment that we are only beginning to understand. Ample evidence exists that many rivers and estuaries were polluted by industrial waste before 1900 and will require major efforts to restore.[1] More recently, stories of the effects of pollution in Lake Michigan and Lake Erie have attracted considerable attention.

Construction activities are increasing rapidly in the coastal zone as population pressure mounts and economic development continues to expand. The impact on the coastal environment and ecology is evident as works associated with modern technology alter the tidal regimen, and degrade or enhance shore and water areas of substantial value.

Land fill and dredging, harbor and channel construction, jetties and breakwaters, causeways, hurricane barriers, salinity control structures, and artificial beaches may generate important ecological changes. In present knowledge, many effects are obscure and a better understanding of relationships is needed. Systematic studies of preventive or corrective action and a full evaluation of man's effects are necessary to realize the potential and to prevent destruction of our coastal resources.

Based upon the material made available to us and the great interest we have noted, the following problems have been identified involving natural and artificial changes in our coastal environment.

–Pollution

–Shoreline erosion

–Shoreline damage from storms

–Loss of wildlife and nutrient areas

–Silting and shoaling

–Eutrophication

–Proliferation of pests and unwanted species.

Pollution, the most severe problem, has been singled out for special emphasis in Chapter 4. The others are discussed in the following sections. Such other problems as shoreline subsidence, ecological disruptions, and socioeconomic and legal considerations are discussed where associated with the more fundamental cause or in other reports of the panel or the Commission.

I. SHORELINE EROSION

Erosion of beaches and shorelines is a serious National problem. Shoreline erosion is due to both natural and man-made effects. Sand is a diminishing important natural resource and its conservation must be considered in long-range planning. The Corps of Engineers reports that about 65 per cent of the Nation's coastline is inadequately protected or endangered.[2]

The principal factors in shoreline erosion are:

–Damage by storms

–Shoreline construction affecting beach processes

–Inland development that curtails normal beach sand nourishment.

The U.S. coastline (including Alaska, Hawaii, Puerto Rico, and the Virgin Islands) is 89,548 miles, of which Alaska alone accounts for 33,900 miles.[3] This mileage includes tidewater areas up to locations where the stream or embayment width becomes less than 100 feet. To this can be added the 4,776-mile U.S. shoreline of the Great Lakes, for a total of 94,324 miles.

The characteristics of these shores may vary from the broken, varying shoreline of New England to the broad sand beaches of the Gulf and Pacific; from the low tidewater backshores of the

[1] *Restoring the Quality of Our Environment,* Report of the Environmental Pollution Panel of the President's Science Advisory Committee.

[2] *Annual Report of the Corps of Engineers,* Vol. 2, 1966.

[3] Coast and Geodetic Survey, *Shore and Sea Boundaries,* Publication 10-1, 1964.

Figure 1. *Storm waves striking a Florida coast. Planned use of the coastal zone must include protection against the flooding and erosion effects of storms. (U.S. Weather Bureau photo)*

Carolinas to the coral shores of the Hawaiian Islands. The combined forces of nature are continually eroding and, at some locations, building up the beaches along U.S. seacoasts.

The erosion problems are many and varied; they are pressing in some areas and of little immediate concern in others. The Corps of Engineers estimates that about 56,000 miles of shoreline need some type of assessment of erosion problems. Of this about 16,000 miles already have been studied and about 7,000 miles currently are being studied (1967).[4] A breakdown by States is given in Table 1.

The most critical areas requiring restoration or nourishment are the entire Atlantic shoreline of New Jersey, the coastline of Florida between Cape Kennedy and Miami, the Gulf of Mexico shoreline in the vicinity of Galveston, the California shoreline from Santa Barbara to San Diego, and the south shoreline of Lake Erie.[5]

[4]Information on Federal Shore Protection Activities, Report by Corps of Engineers, Nov. 28, 1967.

[5]*Shore and Beach Protection*, Corps of Engineers, Coastal Engineering Research Center, July 21, 1967.

It is not realized that sand is a rapidly diminishing natural resource. Once carried to our shores in abundant supply by streams, rivers, and glaciers, geological processes are such that large areas of our coast receive no supply from these sources.[6]

Currently, with few exceptions, streams are adding little material to the beaches, and loss from the beaches is essentially permanent. Development of inland areas tends further to affect erosion of the upland with results in reduced in sand supply to the shore. The construction of dams and the curtailment of stream flow further reduces the coarse sediment load carried to our coastal zone.

For some time, the source of sand for beach restoration and nourishment has been from lagoonal and inland deposits. However, recently it has become increasingly difficult economically to obtain suitable sand from these sources in sufficient quantity for beach fill purposes. This is due primarily to the increased value of marginal and inland lands, including development by public and

[6]*Land Against the Sea*, U.S. Army Coastal Engineering Research Center Misc. Paper 4-64, May 1964.

Table 1
SHORELINE STUDIES AND NEEDS - 1967

State	Total shore	Shore studied	Shore being studied	Appraisal needed
Maine	3,478	10	....	3,000
New Hampshire	131	18	....	....
Massachusetts	1,519	245	5	1,000
Rhode Island	384	40	....	300
Connecticut	618	618	....	....
New York:				
Atlantic	1,850	200	150	500
Great Lakes	408	8	....	400
New Jersey	1,792	200	150	100
Delaware	381	200	200	100
Maryland	3,190	....	3,190	....
Virginia	3,315	15	3,200	100
North Carolina	3,375	400	....	....
South Carolina	2,876	300	....	2,000
Georgia	2,314	200	....	1,000
Florida	8,426	8,426	500	....
Puerto Rico and Virgin Islands	875	24	50	800
Alabama	607	20	....	500
Mississippi	359	50	....	300
Louisiana	7,721	50	10	7,000
Texas	3,359	50	10	3,000
California	3,427	3,000	100	200
Oregon	1,410	....	....	1,000
Washington	3,026	10	....	3,000
Alaska	33,904	10	5	5,000
Hawaii	1,092	1,000	....	....
Pennsylvania	140	20	....	....
Ohio	312	312	5	....
Michigan	2,883	32	....	2,800
Indiana	45	....	....	45
Illinois	83	83	....	....
Wisconsin	820	100	....	700
Minnesota	188	....	....	188
Total	94,324	15,621	7,575	33,034

private interests, and the added cost of transporting sand from remote inland areas. Materials composing the bottom and sub-bottom of estuaries, lagoons and bays, in many instances, are not suitable for long-term stabilization.

Regardless of suitability, restraint also is increasing in the use of any materials in tideland areas, as evidenced by the many laws and ordinances prohibiting such use due to the potential ecological imbalances that may result.

It thus becomes apparent that consideration must be given to conserving sand to the most practicable extent. This does not mean local hoarding of beach sand at the expense of adjoining areas but rather the elimination of wasteful practices and the prevention of losses whenever feasible.

Mechanical bypassing of sand at coastal inlets (Figure 2) is one means of conservation that should come into increasing use. Removal of beach sand for building purposes, formerly common, is rapidly being curtailed as coastal communities learn the need to regulate this practice. Modern hopper dredges, used for channel maintenance in coastal inlets, are being equipped with pump-out capabilities so their loads can be discharged on the shore instead of being dumped at sea. Losses from this practice are expected to be eliminated ultimately.

On the California coast, where large volumes of sand are lost into deep submarine canyons near the

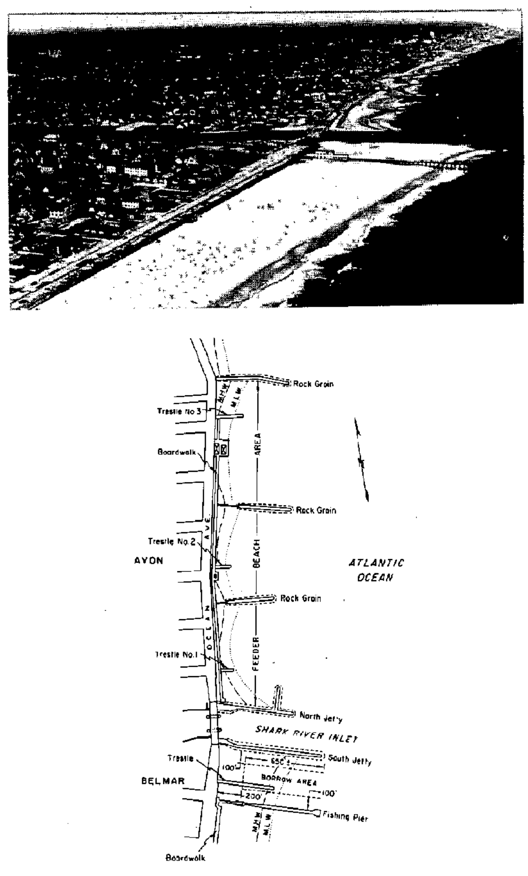


Figure 2. *Construction of harbor breakwaters may disrupt the longshore movement of beach sand replenishment as shown here at Shark River Inlet, New Jersey. The Corps of Engineers has installed a sand bypassing facility which transports sand from the "borrow area" south of the inlet to three "feeder" areas on the north side. (U.S. Army Corps of Engineers photo)*

shore, facilities are being provided to trap the sand before it reaches the canyons and transport it mechanically to a point where it can resume normal beach movement. Planting dunes with appropriate grasses and shrubs reduces windborne losses and aids in preservation.

The Corps of Engineers has been authorized by Congress[7] to conduct a National Study of Shoreline Erosion. This will be a three-year study dealing with the overall problems of beach erosion and including advisory services to State and local activities.

The Corps also proposes to expand a program initiated in 1964 to determine if large deposits of suitable fill material exist in the offshore zone. The program involves the accumulation of data on the characteristics of material composing the bottom and sub-bottom between the 15 foot and 100 foot depth contours.

Since 1964 sand inventories have been completed along the New Jersey and Florida coastlines. Preliminary analysis of data indicates many large deposits of suitable material in the offshore zone. For example, about 600 million cubic yards of suitable material are off the Florida coastline and about 1.5 billion cubic yards along the New Jersey coastline, at distances ranging from one to six miles offshore.

Data have recently been collected along the New England coastline and the area from Cape Charles, Virginia, to the North Carolina line. The remainder of the Atlantic and the Gulf, Pacific, and Great Lakes offshore sand deposits are proposed for study in future years as required. The present problem is to develop the best method of placing offshore deposits on the eroded beaches and additionally provide a better means of creating artificial islands and providing harbor channels. We have much to learn about beach erosion and shore protection and not all our past efforts in this area have been successful.

Available methods of shore protection are of two general types. The first consists of interposing structures to prevent waves from reaching erodible material, such as offshore breakwaters, seawalls, bulkheads, and revetments. The second consists generally of stabilizing or restoring a beach by reducing the rate of loss or increasing the rate of supply or a combination of the two. The loss rate may be reduced by means of impermeable groins or jetties, or it may be compensated for by periodic "nourishment" by adding sand on the beach.

The most suitable method depends upon characteristics of a particular area. A beach is the most effective absorber of wave energy. Therefore, a protective beach is frequently the most suitable measure. However, it is often not feasible to retain a beach on headlands or exposed shores, and a type of armoring of the shore must be used. Protection of a short individual property on an eroding shore is uneconomical, as the adjacent shores will continue to recede and the protection will be outflanked.

Early efforts at shore protection used groins. However, since sand moves along shore, groins which can abstract normal sand movement along the beach often cause erosion of adjacent shores farther in the direction of along-shore transport. Examples of failure to obtain satisfactory results by use of groins alone can be found in New Jersey, Palm Beach and Miami Beach, Florida, and the Presque Isle Peninsula, Pennsylvania.

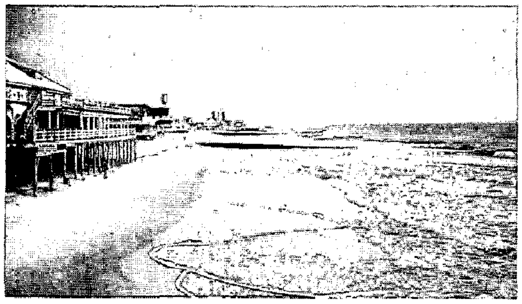
Typical of present methods of protection is the Wrightsville Beach, North Carolina project, which combines beach erosion and hurricane protection.

Wrightsville Beach is a small island off the souteast coast of the State, about 10 miles east of Wilmington. It is separated from other portions of the barrier beach by Moore Inlet at the north, by Masonboro Inlet at the south, and from the mainland by a sound about 1¼ miles wide, consisting of open channels, salt marsh, a small island (Harbor Island), and the Atlantic Intracoastal Waterway.

Here a dune with a top width of 25 feet and a top elevation of 12 feet above mean low water was constructed. The inshore toe of the dune is at or near the building line. Figure 3 shows the beach before and after restoration.

One of the first requirements for coastal planning is adequate technical knowledge of shore processes, storm frequencies, and storm-tide elevations for the area concerned. On our Pacific Coast, including Alaska and Hawaii, the effects of tsunamis (earthquake-generated waves) also must be considered. This information, applied to the topography of the coastal area and the adjoining

[7]River and Harbor Act of 1968, Public Law 90-483, 82 Stat. 731, Aug. 13, 1968 (formerly S. 1262 of the 90th Congress).



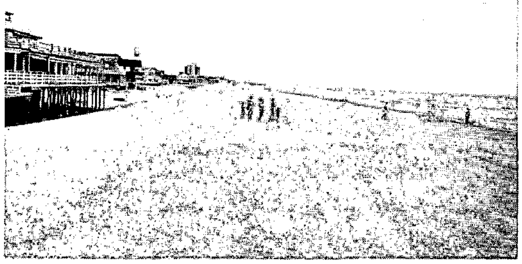


Figure 3. *Beach restoration at Wrightsville Beach, North Carolina. Upper photo shows severe erosion; lower shows same beach after restoration. (U.S. Army Corps of Engineers photos)*

Continental Shelf, makes possible the prediction of flooding and erosion hazards in each area. Such knowledge may then guide the establishment of local zoning and building regulations as well as the needs, types, and dimensions of flood prevention and erosion control.

In highly developed areas the value of lands and improvements, and other economic considerations, will usually ensure the provision of protective works. Timely construction of such works, will ensure the preservation of existing resources and values. Correction of zoning and building regulations in developed areas cannot rectify past errors, but can aid in attaining the long-range development objective.

Underdeveloped areas offer a much more fertile field for advance planning and development control. Procedures can be adopted to conserve remaining natural protective features. Regulation can minimize the costs of protective measures, can ensure that adequate protection is provided before

Table 2

MAJOR STORMS ON THE ATLANTIC AND GULF COASTS FROM 1954–1967

Storm	Area	(United States) Deaths	Damage $Millions
1954–Carol	Atlantic coast	60	439
1954–Edna	New England	21	41
1954–Hazel	Mid–Atlantic	95	200
1955–Connie	Carolinas	25	46
1955–Diane	Atlantic coast	184	832
1955–Ione	North Carolina	7	42
1956–Flossy	Gulf of Mexico	15	10
1957–Audrey	Gulf of Mexico	390	138
1958–Helene	North Carolina	0	11
1959–Gracie	Mid–Atlantic	0	14
1960–Donna	Atlantic coast	50	426
1961–Carla	Texas	46	408
1962–March Storm	Atlantic coast	33	200
1964–Cleo	Florida-Virginia	3	130
1964–Dora	Florida	5	250
1964–Hilda	Louisiana	38	125
1965–Betsy	Florida-Louisiana	75	1,420
1967–Beulah	Texas	15	208
1968–Gilda	Florida	2	–
Average Annual Damage $353 Million			

Source: Environmental Science Services Administration.

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it is too late, and can maintain substantial areas of the coast in its natural or near-natural state.

Protection of our seacoasts is by no means an insurmountable problem. It is a task and a responsibility that has increased in importance in the past 50 years and is destined to become of even greater importance.

While the cost will mount as time passes, it will be possible through careful planning, adequate control, and sound engineering to do the job properly.

II. SHORELINE DAMAGE BY STORMS

Protection of the shoreline and its associated nearshore and offshore activities from storms is of vital importance to the development and use of the coastal environment. This protection includes:

–Shoreline stabilization and beach protection

–Protection of estuaries, harbors, and ports against wave damage

–Improved forecasts of storms and waves.

Much previous discussion on shoreline erosion also is applicable here inasmuch as the more striking results of shoreline erosion are caused by severe weather and storms.

Damages due to particular storms during the period 1954-1968 are shown in Table 2.[8]

A chart showing principal storm tracks affecting the Atlantic and Gulf Coasts is shown in Figure 4.

Panel hearings which offshore industries indicated that, from the standpoint of safety and economy, improvements in environmental predictions are vital to these industries.

Storm protection for backshore areas (as contrasted to beach stabilization) is handled under a separate policy initiated in 1958 as a result of a

[8] Figures furnished by Environmental Science Services Administration. Damages are approximate based on best available records.

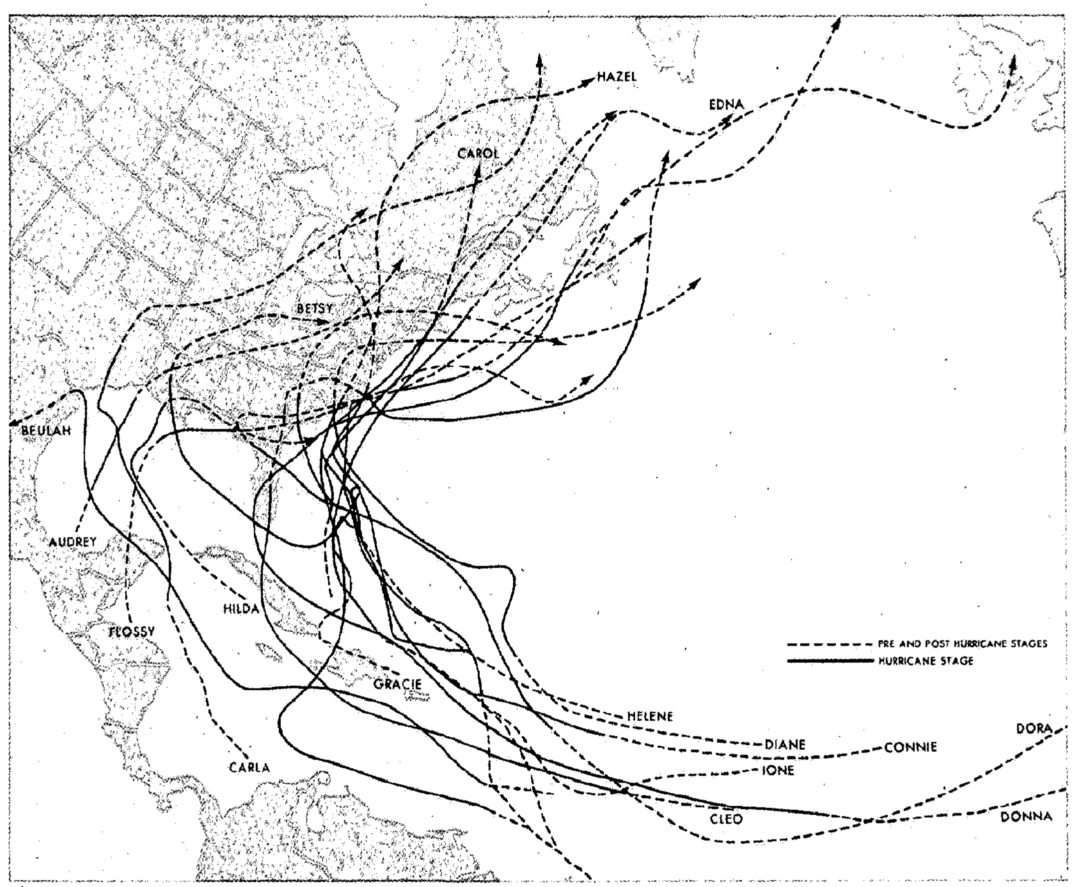


Figure 4. *Major Atlantic storm tracks 1954-1967. (Source: Environmental Science Services Administration)*

series of hurricanes along the Atlantic Coast in the 1950's.

A complicating factor is that Federal participation in coastal storm protection is more liberal than that provided in shore stabilization. Federal aid in construction is 100 per cent for Federal frontage and up to 70 per cent for all other frontages regardless of ownership. No distinction is made between public and private frontages and benefits. Some 30 Federal projects have been instituted for storm protection, 10 of which are either completed or under construction. An example is the protection barrier constructed in 1966 at New Bedford-Fairhaven Harbor, Massachusetts, shown in Figure 5. This project, with a total cost of about $18 million, had a Federal share of about $11 million. It provides adequate storm protection for a 1,400-acre estuarine area.

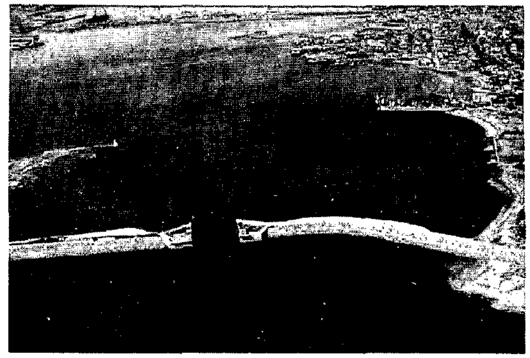
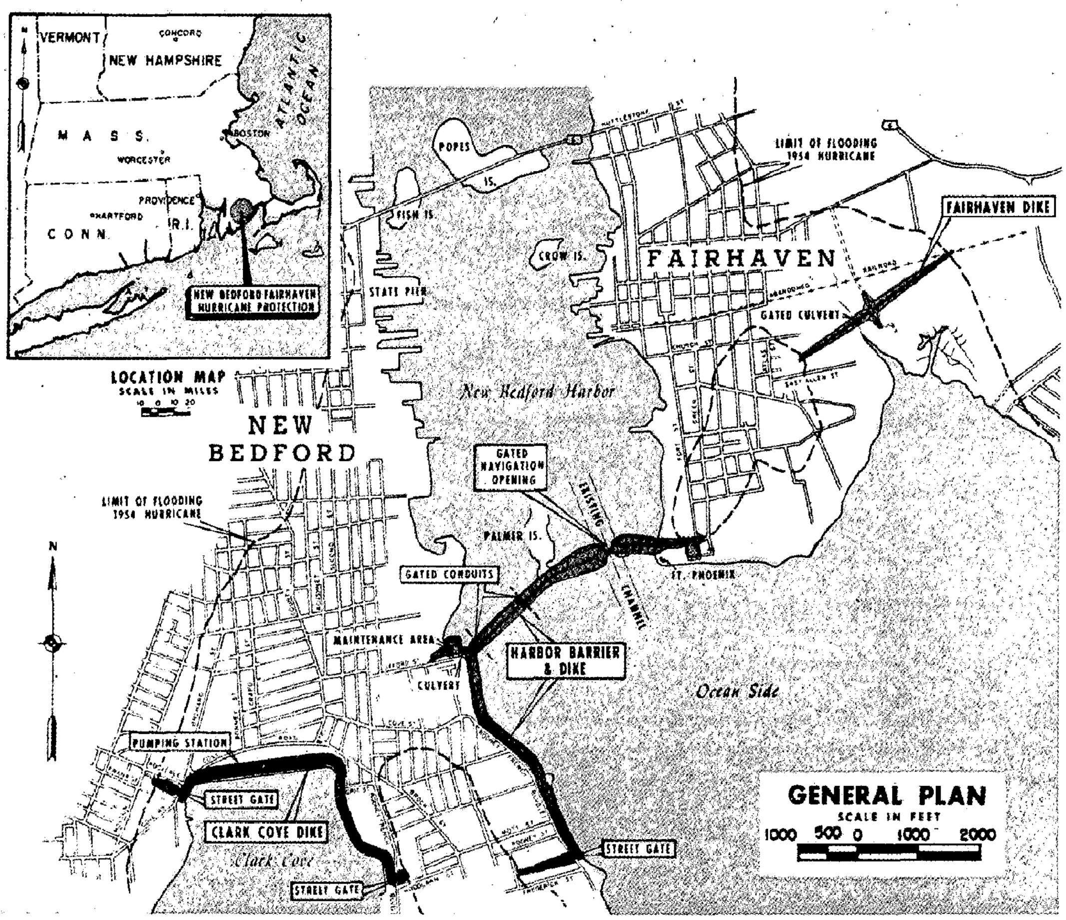


Figure 5. *New Bedford, Massachusetts, harbor hurricane protection barrier. This barrier protects 1,730 acres of coastland from damage which reached $33 million in the 1954 hurricane. (U.S. Army Corps of Engineers photo)*



However, such projects have aroused controversy concerning the possible harmful effects on wildlife and pollution flushing rates.

A massive project proposed by a Corps of Engineers Study[9] responding to Congressional action envisioned a storm protection barrier across the mouth of Narragansett Bay. The proposed barrier was opposed by many interests on the grounds that it would adversely affect recreation, water quality, and fishery resources in the Bay. Responding to the many questions raised, the Army reported against the project to Congress.

Combined hurricane protection and beach stabilization projects such as the Wrightsville Beach, North Carolina, described in the preceding section met with greater favor. The multiple benefits of shore protection and recreation are more apparent.

III. DREDGING AND FILLING

Dredging and/or filling in coastal waters is the means by which most shoreline and port development is accomplished. It constitutes one of the major controversial issues today and perhaps the most severe problem of the future.

Dredging can be defined as the removal of submerged material from the water bottom and can include the placement of such material as fill, or the overboard dumping of dredged spoil into adjacent waters of an estuary or lake.

Dredging is carried on for a variety of reasons:

–Creation and maintenance of navigable channels and inlets for commercial and recreational use

–Creation of useful property, marinas, and recreational areas

–Improved flushing action in bays and estuarine creeks

–Commercial mining of sand, gravel, and oyster shell.

Much debate arises out of lack of knowledge about the consequences of dredging. The areas needing clarification include:

–Influence of dredging on fish and shellfish ecology

–Value of bottom rehabilitation by means of dredging

–Effect of dredging on salt water intrusion

–Pollution control versus salinity control

–Effect of dredging of inlets and their stabilization

–Disposition of dredging spoil.

Presently the principal control over dredging and filling operations is incident to obstruction to navigable waters by the River and Harbor Act of 1899[10] and control is administered by the Corps of Engineers on a permit basis.

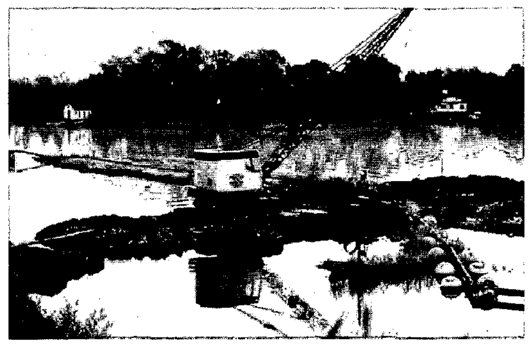


Figure 6. *Dredging and filling of estuaries has become a highly controversial issue. Estuaries are necessary to the life cycles of many important fish species. (U.S. Bureau of Sport Fisheries and Wildlife photo by John Clark)*

Because of the responsibilities inferred by the Federal Water Pollution Control Act,[11] the Fish and Wildlife Coordination Act[12] and the Executive Order on Federal Water Pollution Activity[13] and the proposed legislative threat of a "dual permit" system, the Secretary of Interior and Army enacted a "Memorandum of Understanding" on July 13, 1967 in which the Corps of Engineers would consider the effects on fish and wildlife, recreation, and pollution in the Corps of Engineers navigation control projects and in the issuance

[9] Act of June 15, 1955, Public Law 84-71, 69 Stat. 131, authorized a hurricane survey of the Narraganset Bay area. The report is House Document No. 450, 89th Congress, May 31, 1966.

[10] Act of March 3, 1899, 30 Stat. 1151, 33 U.S.C. 401-418.

[11] Act of July 17, 1952, as amended, 66 Stat. 755, 16 U.S.C. 466-466k.

[12] Act of March 10, 1934, as amended, 48 Stat. 401, 16 U.S.C. 661-666c.

[13] Executive Order 11288, July 2, 1966. This order requires compliance, insofar as practicable, by Federal departments and agencies with the Federal Water Pollution Control Act (33 U.S.C. 666h).

of Corps permits. However, a recent court order[14] indicates that this arrangement may not be a means of effective control.

Spoil disposal from dredging operations is a significant hindrance to the increased utilization of coastal and estuarine waters. Maintaining waterways and dredging them deeper produces great amounts of spoil to be disposed of. Despite careful diking or other placing, spoils often encroach on valuable wildlife or shellfish lands. Spoil dumped in deeper water may degrade water quality and cause undesirable sedimentation.

IV. LOSS OF WILDLIFE AND NUTRIENT-RICH AREAS

Among the more serious effects man is producing on the coastal environment is the loss of wildlife and nutrient areas, principally in the estuarine regions. The central causes are identified as pollution and the filling of marshlands.

As noted in Chapter 2, coastal and estuarine waters and marshlands are vital to the life support of about two-thirds of the entire fisheries harvest. During the past 20 years about seven per cent of important estuarine fish and wildlife habitat has been lost to shorelands development.

Research reported in 1960 by Dr. E. P. Odom[15] showed the productivity of Georgia estuarine waters to be about 10 tons of dry organic matter per acre per year. This is nearly twice that of the best agriculture lands and approximately seven times greater than Continental Shelf fishing banks, and 20 times greater than the open ocean.

Located at the mouths of rivers, estuaries are particularly vulnerable to the ill effects of pollution and sediment from the river basin and from the great coastal cities that have arisen from the early centers of ocean commerce. At the same time, land fills, dredging, draining of marshes, and dumping reduce their surface areas. For example, about 80 per cent of the 300 square miles of tidal wetlands that originally surrounded San Francisco Bay have been lost.[16]

Table 3, prepared by the Fish and Wildlife Service,[17] shows a summary of a 20-year record of the loss of important fish and wildlife estuarine habitat.

Of the tidal wetlands along our North Atlantic Coast, from Maine to Delaware, 45,000 acres of marshland were destroyed in the 10-year period 1955-1964. An inventory kept in the last five of those years shows that 34 per cent was lost to dredge spoil deposit; 27 per cent to fill for housing developments; 15 per cent to recreational development (parks, beaches, marina); 10 per cent to bridges, roads, parking lots, and airports; 7 per cent to industrial sites; 6 per cent to garbage and trash dumps; and 1 per cent to other causes.[18]

Awareness of this problem is growing and States have taken action. Rhode Island passed a Marshland Zoning Act in 1965 (H-1643) to restrict use of coastal wetlands to public health, marine fisheries, wildlife and other conservation purposes. The Rhode Island Department of Natural Resources has gained some measure of zoning power over the marshes from this legislation.

A large-scale survey of that State's wetlands led to designation of areas that should be protected. Priorities have been assigned to areas deemed valuable. An acquisition program has begun, and under it the State was authorized to purchase marshland and hold it in public ownership for conservation.

In 1963 and 1965, Massachusetts passed amendments to its Coastal Wetlands Laws which gave authority for protection of wetlands. The State can acquire land by eminent domain and compensate the owner when the action amounts to land-taking. Also the State was given authority to establish regulations and restrictions to govern wetlands alterations.

In the first court action since enactment of the Massachusetts Coastal Wetlands Laws, the right of the State to prevent a construction firm from filling over a marsh with dredge spoil was upheld.[19] The court ruled that "Marsh is . . .

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[14] *Zabel* v. *Tabb*, No. 67-200, Civ-T, Middle District, Florida, March 14, 1968. See discussion of this case in Chapter 8.

[15] Eugene P. Odum, "Estuarine Agriculture," in *Symposium on Estuarine Ecology: Coastal Waters of North Carolina*, University of North Carolina, 1966.

[16] Report of the San Francisco Bay Conservation and Development Commission, 1968.

[17] Report of Bureau of Sport Fisheries and Wildlife to House Merchant Marine and Fisheries Committee, 90th Congress, March 6, 1967.

[18] Report of Bureau of Sport Fisheries and Wildlife to the National Audobon Society Convention, Boston, Massachusetts, October 1965.

[19] *Commission of Natural Resources* v. *S. Volpe & Co.*, 349 Mass. 104, 206 N.E.2d 666 (1965).

Table 3
LOSS OF WILDLIFE AND NUTRIENT AREAS

State	Acres of estuaries: Total area (thousands)	Area of important habitat (thousands)	Area lost by dredging and filling (thousands)	Per cent loss of habitat
Alabama	530	133	2	1.5
Alaska	11,023	574	1	.2
California	552	382	256	67.0
Connecticut	32	20	2	10.3
Delaware	396	152	9	5.6
Florida	1,051	796	60	7.5
Georgia	171	125	1	.6
Louisiana	3,545	2,077	65	3.1
Maine	39	15	1	6.5
Maryland	1,406	376	1	.3
Massachusetts	207	31	2	6.5
Michigan[1]	152	152	4	2.3
Mississippi	251	76	2	2.2
New Hampshire	12	10	1	10.0
New Jersey	778	411	54	13.1
New York	377	133	20	15.0
New York State (Great Lakes)	49	49	1	1.2
North Carolina	2,207	794	8	1.0
Ohio[1]	37	37	[2]	.3
Oregon	58	20	1	3.5
Pennsylvania[1]	5	5	[2]	2.0
Rhode Island	95	15	1	6.1
South Carolina	428	269	4	1.6
Texas	1,344	828	68	8.2
Virginia	1,670	428	2	.6
Washington	194	96	4	4.5
Wisconsin[1]	11	11	[2]	.0
Total	26,618	7,988	569	7.1

Source: Fish and Wildlife Service.

[1] In Great Lakes only shoals (areas less than 6 feet deep) were considered as estuaries.
[2] Less than 500 acres.

necessary to preserve and protect marine fisheries."

A significant part of the problem in destruction of coastal habitats is the loss or restriction of sport or commercial shellfishing due to shorelands development or pollution. A current survey[20] of shoreline uses by coastal states showed the greatest areas lost were shellfish grounds. Of 22 seacoast States, loss of important habitat was reported for oysters and crabs in 18, clams in 14 and shrimp in 10.

Early maps of the San Francisco Bay Area show nearly all shoal waters producing oysters and clams. Recent studies[21] estimate 175,000 acres of potential oyster bottom remain, including areas

[20] John I. Thompson & Co., *A Perspective of Regional and State Marine Environmental Activities,* contract report to the Institute of Public Administration, February 1968.

[21] Report of the San Francisco Bay Conservation and Development Commission, 1968.

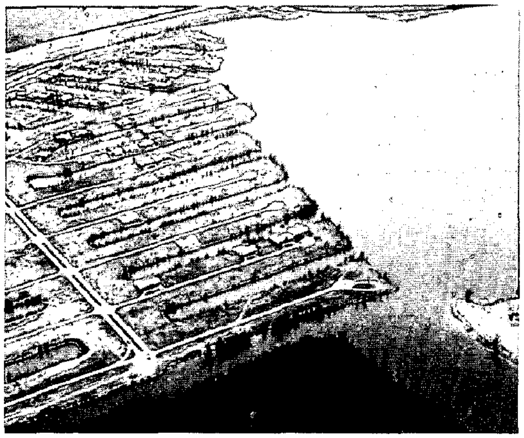

Figure 7. *In the last 20 years more than seven percent of the Nation's important estuarine area has been lost, principally to housing development. (U.S. Bureau of Sport Fisheries and Wildlife photo by Richard Stone)*

contaminated by pollution. Since an estimated 83 per cent of estuarine marshlands has been eliminated in San Francisco Bay, one may calculate at least an equal loss of oyster bottom, or about 825,000 acres. In 1936, 6½ million pounds of Bay shrimp were harvested, but only 10,000 pounds in 1966. Softshell clams have vanished from the Bay.

At the peak of the Connecticut shellfish industry in 1900, approximately 27,000 acres of marshland existed.[22] Today only approximately 9,000 acres remain and the rate of loss is alarming. In Fairfield County alone between 1954 and 1964, 933 acres of marshland or 45 per cent of the marshland that existed in 1954 were destroyed by development. Of Fairfield County's remaining 1,100 acres of marshland, only approximately 100 acres is assured as a wildlife preserve. Thirty per cent of the shellfish grounds in Connecticut presently are closed by the State Health Department because of poor water quality.

Mosquito control projects have devastating side effects on fish and other aquatic life. Although DDT and other insecticide pollutants are the most dramatic killers, there are other damaging control activities.

Drying marshes by cutting drainage ditches is a popular method of preventing mosquitoes from breeding. This has complicated effects in relation to aquatic life. Ditches at sea level can be beneficial by providing entry to the marsh for fish, by allowing better irrigation of the marsh by tidal action, and by facilitating passage of nutrients out of the marsh to the bay. Impounding marshes with dikes or levees to prevent mosquito breeding tends to make fresh water lagoons of the marshes and to eliminate them as places which can support marine and brackish-water life.

Here the conflict of public interests requires a balancing of the value of marine fish resources against the nuisance of mosquitoes. Furthermore, diking proposals also may involve balancing benefits to marine fish resources against benefits to waterfowl and fresh water fish resources, since current waterfowl improvement techniques often involve diking off salt water areas to create fresh water impoundments.

V. MODIFICATION AND DIVERSION OF FLOW

Coastal engineering projects such as harbor channels, power plant and flood control diversions can affect the circulation, flushing and mixing dynamics of coastal or adjacent waters.

Estuarine waters usually are low in salinity, with salt water from the sea continually being diluted with fresh water from rivers. This dilution sets up a pattern of decreasing salinity from the ocean, up through the bays and into the tidal rivers. Since the whole variety of estuarine life is adjusted to salinity patterns, changing them can have disruptive effects.

Many human activities affect the quantity of fresh water inflow, its temporal distribution, and contents. River flow can be reduced, especially by diversion for cities, for irrigation of agricultural land, and by intentional or accidental use of spillways or breaks in levees.

Conversely, flow is increased in the basins receiving the diversion. Frequently, increased total output is the result of denuding the watershed by removing vegetation and by other activities that decrease absorption and subsurface retention. Increase in runoff is especially vivid in paved urban areas and along highways where as much as 30 acres per mile is paved or carefully sloped to maximize runoff.[23] As a consequence, there is

[22] Report of J. Richard Nelson, Chairman, Connecticut Shellfish Commission to Subcommittee on Fisheries and Wildlife Conservation of the House Merchant Marine and Fisheries Committee, March 1967. Other statistics in this paragraph also come from this report.

[23] C. E. Renn, "Man as a Factor in the Coastal Environment," *Transactions of North American Wildlife Conference*, 1956.

greater variation in river flow, greater flooding in high-flow periods, and drought in low-flow seasons.

Counteracting forces do exist, however, in improved general conservation practices and in the increasing number of small and large dams, many specifically designed for moderation of river flow and planned release of water.

Dams can interrupt natural flow and salinity levels by storing fresh water for long periods and then quickly releasing large quantities. The intermittant flow, with sudden changes in salinity and heavy silt load, may be a strong deterrent to fish and bottom life.

However, the converse, reducing large seasonal variations in fresh water flow by controlling the river discharge through dams and low-flow augmentation can cause problems. For example, circulation in the small tributary embayments of Chesapeake Bay is produced by salinity differences between the tributary and the Bay proper.[24] Since the water is derived from the main Bay, the salinity in the tributary must lag behind Bay salinity. If the Susquehanna River discharge were to be controlled to the extent that seasonal changes in upper Bay salinity disappeared, then the prime mechanism for flushing of several tributaries also would disappear. Pollution problems within the tributaries would increase and lead to significant ecological effects.

Engineers concerned with estuarine environment problems also have become keenly aware in recent years that the amount of fresh water discharged into an estuary, and the degree to which it mixes with sea water, are major factors in establishing the hydraulic and shoaling regimens of the estuary.

An example of what can happen by a change in the density structure of estuarine waters is Charleston Harbor, located at the mouth of the Cooper River. Prior to a water diversion made in 1942, the amount of fresh water flowing down the Cooper into the estuary was small compared to the inflow and outflow of the tide, and the estuary was vertically homogeneous. When fresh water was added from the Santee River to provide a source of hydroelectric power, it changed into a two-layered flow pattern with a surface layer flowing seaward and a deeper layer flowing up the estuary. Thus, Charleston Harbor became a trap for the increased amounts of sediment, and dredging required to maintain the channel has increased from less than 500,000 cubic yards prior to 1942 to a current volume of over 10,000,000 cubic yards.

One proposed solution[25] to Cooper River shoaling is to divert the water back into the Santee River. This is an alternative to an original proposal to divert the fresh water into a high-salinity coastal marsh habitat which would have had a serious effect on valuable fish nursery grounds (see Figure 8).

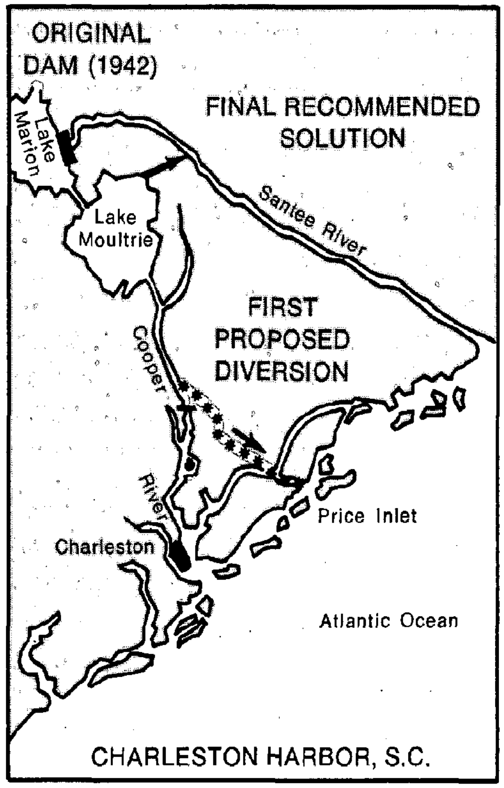

Figure 8. *Water diversion: Cooper and Santee Rivers, South Carolina.*

A coastal bay or estuary has a complex ecology related to the physical characteristics of its basin. Natural processes such as storms and slow climatic changes will disturb this balance and man can drastically alter it.

Coastal and inlet deep draft channel openings can contribute to salinity intrusions while hurri-

[24] D. W. Pritchard, "Modification and Management of Water Flow in Estuaries," *Symposium on Beneficial Modifications to the Marine Environment*, Washington, D.C., 1968.

[25] U.S. Army Corps of Engineers, District, Charleston, *Survey Report on Cooper River, S.C. (Shoaling in Charleston Harbor)*, July 1966.

cane barriers and similar structures can reduce the salinity inflow, with commensurate changes in the ecology of the area.

Water diversion may disturb the migratory patterns of fish. It has been found[26] that the flow reversal in the San Joaquin River, because of exportation of water through a power plant, has apparently affected salmon runs, presumably because "home stream" water was not present to stimulate ascent and spawning. Further, the vigor of estuarine circulation, greatly affected by flow, determines the reproductive rate necessary for maintenance of plankton populations.[27]

Management authority is faced with the difficult task of weighing beneficial aspects against harmful results in deciding on man-made changes to an environment.

[26] D. Gaussle and D. W. Kelley, "The Effect of Flow Reversal on Salmon," in *Annual Report, Delta Fish and Wildlife Protection Study*, 1963.

[27] B. H. Ketchum, "Relation Between Circulation and Planktonic Populations in Estuaries," *Ecology*, Vol. 35, 1954.

An example of tradeoffs is the Bonnet Carre Spillway constructed in 1932 to protect New Orleans from Mississippi River floods. When opened under flood conditions, it diverts water into Lake Pontchartrain, and eventually the Gulf of Mexico. All the receiving area is estuarine. In Lake Pontchartrain, motile organisms are driven out, and many non-motile forms are killed by low salinities. Most or all oysters in mud covered beds are destroyed, with lower loss over a wider area, although oyster pests and predators are also killed. Nutrient is added to the area in great quantities. Following return to normal salinities, unusually great production of shrimp and other marine life is observed. Following a careful study[28] it has been submitted that the total beneficial economic effect outweighs the partial oyster mortalities that occur in some years. A photograph of this project is shown in Figure 9.

[28] G. Gunter, Mortality of Oysters and Abundance of Certain Associates as Related to Salinity, *Ecology*, Vol. 36, 1955.

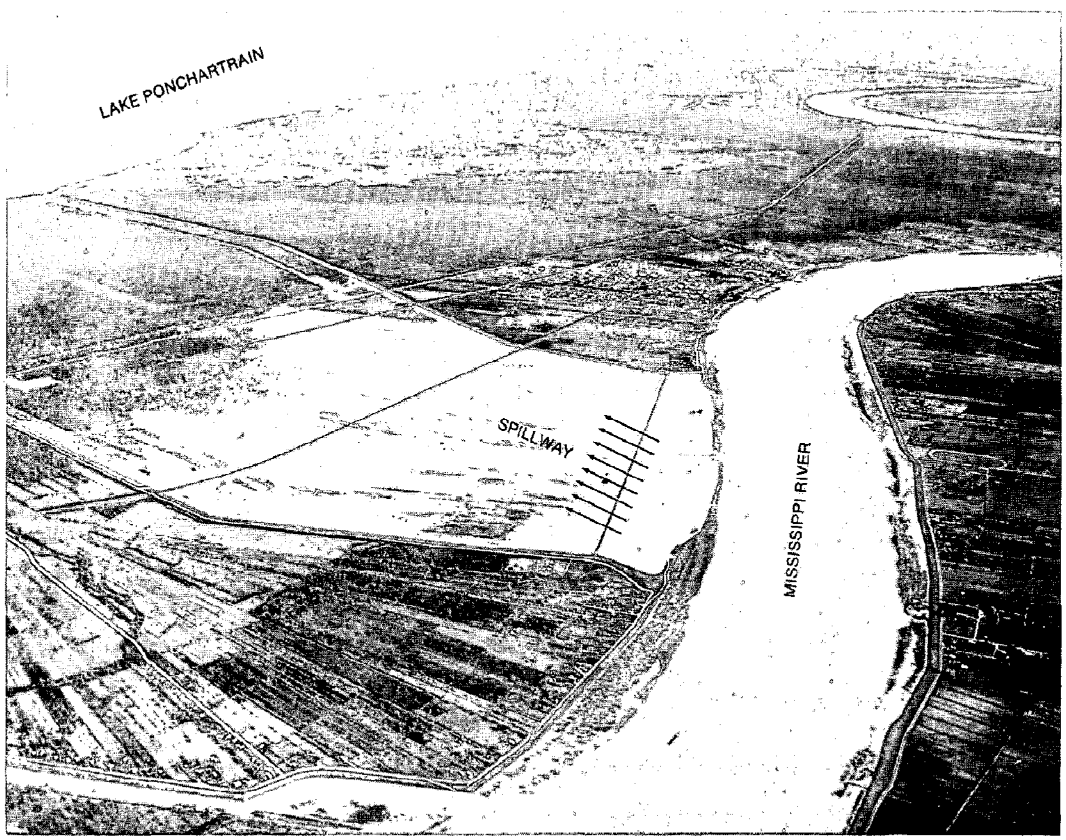

Figure 9. *Bonnet Carre Spillway, Louisiana. Mississippi River floodwater is diverted into saltwaters of Lake Ponchartrain. Here flood protection must be weighed against attendant shellfish losses. (U.S. Army Corps of Engineers photo).*

A classic example of a permanent man-made change is the conversion of the Zuider Zee in the Netherlands from a salt water estuary to a fresh water lake between 1932 and 1940.

This modification added land area and fresh water resources and decreased the vulnerability of the area to winter storms. Valuable mussel and oyster industries were destroyed but a limnetic finfish industry has been established.

Bold actions such as this should be included in long range planning to cope with the increasing demands of the Nation's development. However, planning must always be accompanied by an attempt to understand thoroughly the physical and biological consequences.

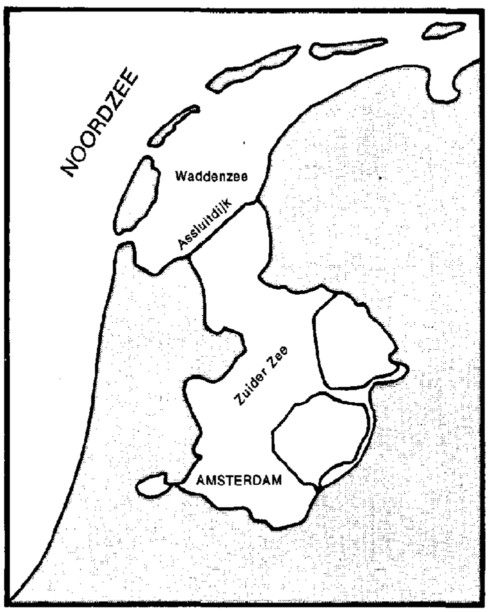

Figure 10. *The old Zuider Zee, cut off by an enclosure dike to convert an estuary to a lake and dry land.*

VI. EUTROPHICATION[29]

Sophisticated instrumentation is hardly necessary to alert the public to the fact that something has gone awry in Lake Erie. People cannot enjoy its use in the same ways that they could 20 years ago. It is also evident that the southern part of Lake Michigan and parts of Lake Ontario exhibit some of the same symptoms as Lake Erie. Dr. David C. Chandler, Director of the Great Lakes Research Division, Institute of Science and Technology, University of Michigan, in testimony before the panel stated that the common denominator limiting the multiple use of the Great Lake resources is water pollution. Most authorities agree.

The Federal Water Pollution Control Administration[30] identifies the major physical problems of the Great Lakes area as:

– Over-enrichment of the lakes

– Build-up of dissolved solids in the lakes

– Bacterial contamination of the lakes and tributaries

– Chemical contamination from industrial waste discharges

– Oxygen depletion of the lakes and tributaries.

Historically, young lakes are relatively barren bodies of water in terms of the amount of biological life which they support. As aging progresses, the material retained by a lake gradually increases in the bottom sediments. Through bacterial and other decomposition of sediments, the lake waters become richer in nutrient materials to which phytoplankton, the population of zooplankton, and higher animal forms respond as the food supply increases. Finally, deposits from biological activity, both organic and inorganic, and materials from the tributary waters fill the basin to the extent that rooted aquatic plants take command and gradually convert the area to marsh land.[31]

The aging process is known as "eutrophication," which can be defined as the process of enrichment with nutrients.[32] Accelerated eutrophication or over-enrichment of the lakes results from the input of nutrient materials, mainly nitrogen and phosphorus, from man's activities.

[29] Much of the material in this section was taken from a contract report of the Commission, Pacific Northwest Laboratories, Battelle Memorial Institute, *Great Lakes Restoration–Review of Potentials and Recommendations for Implementation,* June 17, 1968.

[30] *Water Pollution Problems of the Great Lakes Areas,* 1966.

[31] Clair N. Sawyer, "Basic Concepts of Eutrophication," *Journal Water Pollution Control Federation,* pp. 737-744, May 1966.

[32] K. M. Stewart and G. A. Rohlich, *Eutrophication–A Review,* report to the State Water Quality Control Board, State of California (1967).

Normally, the natural aging process proceeds at a slow pace measured by the geological time scale. However, man has so accelerated this time scale, through his discharge of nutrients to the lakes, that significant aging is observed within a generation.

Accelerated eutrophication is emphasized in this report because it is the most critical problem, in terms of impairment of benefits, facing the Great Lakes. Its remedy will require a number of curative measures. Other problems such as buildup of dissolved solids and oxygen depletion are closely intertwined with eutrophication.[33]

Accelerated eutrophication of Lake Erie is manifest in the following ways:

– Blue-green algal blooms and other algal groups such as diatoms produce noxious odors and at times appear as unsightly scum on the water surface.

– These same algae impart unpleasant tastes to water supplies.

– Dissolved oxygen levels are depressed in thermally stratified areas.

– Bottom-dwelling fauna change from clean water forms to less desirable forms that are tolerant to pollution and low oxygen concentration.

– Fisheries resources have changed from highly prized game fish, such as pike, trout, and whitefish to the coarse, less valuable fish such as carp, catfish, and sheepshead.

– Nuisance filamentous algae growing in shallow waters near shore break loose and wash up onto shores and beaches.

– Unsightly, odorous conglomerates of algal and other pollutants interfere with recreational use of waters and beaches, clog municipal and industrial water intakes, and depress property values.

[33] J. F. Carr, *Dissolved Oxygen in Lake Erie, Past and Present,* University of Michigan Great Lakes Research Division Publication No. 9, pp. 1-14.

Figure 11. *Symptoms of accelerated eutrophication in the Great Lakes include odorous and unsightly algal blooms which foul beaches and deteriorate water quality. (Department of the Interior photo)*

Water quality assessments indicated that nearly all of Lake Erie is eutrophic, Lake Ontario is on the verge of becoming eutrophic, and Lake Michigan is exhibiting some of the symptoms of eutrophy in certain areas, particularly in the southwestern portion. Isolated examples of pollution have been observed in Lakes Huron and Superior, although their water quality is generally considered good.[34]

Oxygen can be depleted through the addition of organic substances to the receiving bodies of water and the proliferation of algae associated with eutrophic conditions. Organic pollutants, where controllable, can be dealt with by implementing treatment methods required to meet water quality standards.

The principal nutrients of concern in the enrichment process of eutrophication are phosphorus and nitrogen compounds. Other nutrients also have been implicated as contributors to accelerated eutrophication, including vitamins, growth hormones, and amino acids. In addition, trace elements are known to play a major role in the process, but their relative importance is ill-defined.[35]

The most important contributors to eutrophication ranked in order are:

– Municipal wastewater

– Sedimentation

– Agricultural runoff.

[34] Alfred M. Beeton, "Indices of Great Lakes Eutrophication," *Proceedings, Ninth Conference on Great Lakes Research,* Great Lakes Research Division, University of Michigan, Publication No. 15, 1966.

[35] E. J. Martin, and L. W. Weinberger, "Eutrophication and Water Pollution," *ibid.*

A. Municipal Wastewater

Nitrogen can be fixed directly from the atmosphere by biological life. But phosphorus is a more readily controllable nutrient. In the Great Lakes the dominant source of nutrients, especially phosphorous, is municipal wastewater, mainly sewage. A Federal Water Pollution Control Agency survey has shown that 75 per cent of the phosphorus added to Lake Erie annually comes from municipal wastewater. Moreover, about 66 per cent of the phosphorus is associated with detergents. Approximately two-thirds of this nutrient is retained in the lake, principally by incorporation in bottom sediments.

Needless to say, the effects of municipal wastewater discharges have drastically effected the aging of the Great Lakes, Lake Erie in particular. There can be no doubt that the discharge of domestic sewage has been a predominating contributor to the deterioration of water quality, not only because of nutrients but also because of bacterial and organic contamination.

Whereas eutrophication is measured on a geological time scale under natural conditions, accelerated eutrophication resulting from man's activities is evident in a single lifetime.

B. Sedimentation

The preceding discussion identified municipal wastewater as the principal source of nutrients in the Great Lakes.[36] Sedimentation, including silts, erosion and agricultural runoff, dead biological life, and wastewater residues, is the second most important source of nutrients.

As silts and erosion runoff flow into a lake, nutrients are dissolved and are available for biological utilization. Land use practices, especially land area development practices in urban as well as agricultural areas, have contributed to the problem. If measures are not undertaken to control this nutrient source, accelerated eutrophication will be rapid, second only to municipal wastewater effects.

C. Agricultural Runoff

Agricultural runoff is also a significant source of nutrients entering the Great Lakes. It is comprised of eroded soil, leached salts and fertilizers, and excess fertilizer. Measures to alleviate some nutrient contribution from agricultural runoff include land management techniques (contour plowing, for example), judicious fertilizer application, and where possible, controlled water addition. Because treatment cannot be applied to point sources, it is difficult to control nutrients in agricultural runoff. This problem is a major one in terms of accelerated eutrophication of the Great Lakes.

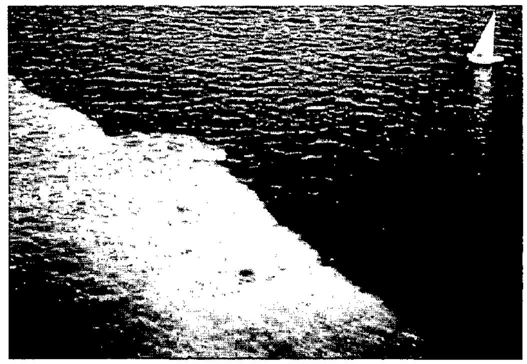

Figure 12. *Eutrophication is a natural, long-term process of lake aging. However man-made accelerated eutrophication through pollution may transform a lake into a swamp within a lifetime. (Department of the Interior photo)*

Other contributors to eutrophication having a lesser but still significant impact are:

- Industrial wastewater
- Combined storm sewage
- Urban land drainage
- Dredging
- Tributary inflow.

Still others have been identified but having a low impact are:

- Watercraft wastes
- Oil discharges
- Thermal discharges
- Waterfowl
- Subsurface disposal
- Atmospheric quality deterioration.

[36]L. R. Webber and D. E. Elrich, "The Soil and Lake Eutrophication," *Proceedings, Tenth Conference on Great Lakes Research, ibid.*, pp. 404-412, 1967.

Obviously, ranking is general and for local problems it may not fit. But in the Great Lakes it indicates orders of magnitude.

Accelerated aging or eutrophication of certain Great Lakes is not the sole cause or symptom of deterioration of water quality. However, because the effects of other pollutants are so intimately linked to this phenomenon, preventing accelerated eutrophication and restoring the water quality in eutrophic lakes will help to improve other quality problems such as oxygen depletion caused by the biodegradation of organic wastes.

It must be realized that predicting what would happen to the eutrophication trend through removal of any single nutrient source is virtually impossible. While priorities should be established to deal with both preventive and restorative techniques, many methods will have to be implemented before effective restoration is achieved.

Any plan for restoring the Great Lakes is a tremendous undertaking because of the scale and nature of resources involved. Technology for dealing with freshwater environments is not oriented toward problems of this magnitude; however, technology in the marine sciences has been directed toward the solution of large scale problems.

Note: Eutrophication, both in the Great Lakes and in general, has been the subject of much research and many scientific and popular articles discuss this topic. Readers will find the following papers useful: Lake Erie Basin Committee, League of Women Voters, *Lake Erie: Requiem or Reprieve?,* 1966; K. M. Stewart and G. A. Rohlich, "Eutrophication–A Review," Publication No. 34, State Water Quality Control Board, State of California, 1967; C. F. Powers and Andrew Robertson, "The Aging Great Lakes," *Scientific American,* pp. 94-104, November 1966; W. J. Oswald and C. G. Golueke, "Eutrophication Trends in the United States–A Problem?, *Journal Water Pollution Control Federation,* pp. 964-974, June 1966; E. G. Fruh, K. M. Stewart, G. F. Lee, and G. A. Rohlich, "Measurements of Eutrophication and Trends," *ibid.,* pp. 1237-1258, August 1966; B. Commoner, "The Killing of a Great Lake," *The 1968 World Book Supplement to the World Book Encyclopedia;* Department of Health, Education and Welfare, U.S. Public Health Service, *Pollution of Lake Erie and Its Tributaries–Part I,* 1965.

VII. PROLIFERATION OF PESTS AND OTHER SPECIES

The existence of or proliferation of unwanted species is a problem of many regions although the types and effects of the species vary considerably. These include:

–Jellyfish: Atlantic coast, especially Chesapeake Bay

–Aquatic Weeds: New England, Long Island, Chesapeake Bay, South Atlantic and Gulf waterways

–Sharks: many coastal areas

–Alewives: Great Lakes.

Marine pests can be a very real problem which can affect the economy and the development of a region.

Man often has contributed to dramatic increases of marine pests by increasing nutrients, accidentally introducing the species, modifying the salinity, or eliminating the predators.

A. Jellyfish

All waters surrounding the United States contain venomous jellyfish and other related organisms. The East Coast and Gulf Coast States are affected at times by invasions of jellyfish, leading to severe restrictions of water-based activities.

The notorious portuguese man-of-war (*Physalia*) is virulent and sometimes so abundant that it forces the closure of major beaches, and gravely damages the image and quality of Florida's greatest asset. The coastal areas of the New England States and New York are subject to intermittent swarms of jellyfish, brought to the inshore areas by vagaries of the coastal currents and winds.

In Chesapeake Bay, the problem is particularly acute because of the summer sea nettle (*Chrysaora quinquecirrha*), which on contact with a bather produces a skin irritation so severe that swimming in Chesapeake Bay virtually ceases when the pests appear from late June to early October. The common sea nettle is umbrella shaped, is about eight inches in diameter and has tenacles streaming up to 30 inches beneath. Under severe conditions as many as 50 sea nettles per cubic yard have been counted.[37] The sea nettle also presents problems to industrial boating and commercial fishing interests by clogging pump intakes and nets, causing nets to rot, and causing skin irritations to those handling these materials.

[37] L. E. Cronin, Director, Chesapeake Biological Laboratory, testimony to House Merchant Marine and Fisheries Committee, Sept. 28, 1967.

In 1967 Congress[38] appropriated $100,000 in matching funds to provide research on control or elimination of jellyfish and other pests.

B. Alewives *(Pomolobus pseudoharengus)*

The unnatural condition of alewives in the Great Lakes, especially Lake Michigan, was caused primarily by the sea lamprey destroying large predator fish. In the absence of predators the alewife thrived to the detriment of other fish.

The explosive increase in recent years and the severe die-off in 1967 were costly to States, communities, and industries on the lake. The West Michigan Tourist Association estimated that resort owners lost more than $50 million in 1967.[39]

Alewives were noted first in Lake Ontario in 1873, a few years after the introduction of shad into that lake. The alewives might have been accidentally included in the plantings of shad.

The Welland Canal was completed in 1829, but it was not an easy route for fish. The first sea lampreys were not found in Lake Erie until 1921. Alewives were reported in Lake Erie in 1931, in Lake Huron in 1933, Lake Michigan in 1949, and Lake Superior in 1954.

The alewive was common in Lake Erie by 1942, but never became extremely abundant. In Lake

[38] Jellyfish Control or Elimination in Coastal Waters Act of November 2, 1966, Public Law 89-720, 80 Stat. 1149.

[39] Special Report to panel by Dr. J. L. McHugh, Deputy Director, Bureau of Commercial Fisheries, Feb. 13, 1968. This and the following material on the alewife problem was taken from that report.

Figure 13. *Alewife die off in Burnham Harbor, Lake Michigan. (Chicago Sun Times photo by Bob Langer)*

Huron a large population of trout and other predators existed in 1930, but sea lampreys virtually eliminated them by the early 1940s. Alewives were abundant in Lake Huron by the mid 1950s. In Lake Superior, they are not yet abundant because of the large number of predators remaining and because of the cold water.

In Lake Michigan large predators were almost gone when the alewives were first found there in 1949. By 1956, they were abundant throughout the Lake and, during the early 1960s, the number of adults more than doubled each year. The population reached a peak in 1966-67. As they increased, yellow perch were crowded from offshore areas.

The best control for alewives is the predator. The introduction of coho salmon in Lakes Michigan and Superior suggests this species may be the most effective predator the lakes have ever known. The coho, introduced by the Michigan Conservation Department in 1966, has had a surprising growth rate. The mature fish average of 12 pounds may be reached in one year. Lake trout normally require 11 years to reach 12 pounds.

However, the introduction of salmon may result in a further imbalance of the ecology of the Great Lakes.

C. Eurasian Milfoil *(Myriophyllum Spicatum)*

This species of aquarium plant, probably introduced into Chesapeake Bay by discarding a household decoration, becomes a nuisance when it forms extensive beds that interfere with boating, swimming, and fishing. Dense beds of milfoil create muddy bottoms by serving as settling basins for silt particles. Extensive beds damage oysters and clams by reducing water circulation and cutting oxygen supplies to them. It was estimated in 1964 that about 100,000 acres of the Bay and its tributaries were infested with milfoil, although some estimates ran as high as 200,000 acres.[40]

Milfoil usually grows in depths less than eight feet, but has been found at 12 feet. It grows best in fresh water but has shown a tolerance of up to 15 parts per thousand salinity, or half the concentration of seawater.

The Rivers and Harbors Act of 1965 designated Eurasion Milfoil a major noxious aquatic plant and authorized the Corps of Engineers to investigate methods of control and eradication.

The University of Maryland[41] has conducted experiments to test milfoil as poultry or cattle food. Results so far show it to be unfavorable as poultry food, but as good as high-quality hay for cattle. However, beginning in 1964 a disease has infected the milfoil in Cheasapeake Bay which threatens to eliminate it as either a nuisance or a use. As the milfoil recedes in Chesapeake Bay, other aquatic plants such as water chestnuts *(Trapa natans)* and sea lettuce *(Ulva ulvaceae)* appear to be taking its place.

D. Water Hyacinths *(Eichornia crassipes)*

For several years the growth of water hyacinths has been an acute problem in South Atlantic and Gulf Coast States. These floating plants choke waterways and obstruct navigation, recreation and fishing. Added nutrients to coastal and estuarine waters appear to increase the plant's proliferation and that of a similar pest, alligatorweed.

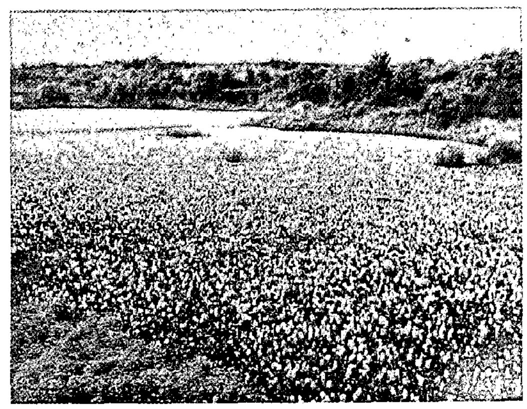

Figure 14. *Water hyacinth jam in a Florida waterway. (U.S. Army Corps of Engineers photo)*

In 1958 legislation[42] first provided for control and progressive eradication of the water hyacinth, alligatorweed, and other obnoxious aquatic plant growths from the navigable waters, tributary streams, connecting channels, and other allied waters in the States of North Carolina, South

[40] Chesapeake Bay Case Study, report by Trident Engineering Associates to the National Council on Marine Resources and Engineering Development, Oct. 20, 1967.

[41] *Ibid.*

[42] Rivers and Harbors Act of July 3, 1958.

Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas.

The 1958 Act provided that 70 per cent of the cost would be borne by the United States and 30 per cent by local interests. The Rivers and Harbors Act of 1965 further modified the project: that, effective in 1968, all planning is wholly a Federal obligation, that the project area shall include all States, and that Eurasian milfoil is named with water hyacinth and alligatorweed as major obnoxious aquatic plants.

Man easily surpasses nature in his energy and inventiveness in polluting his environment. A river abrades its banks and muddies the downstream waters. A hurricane tears at a shoreline and buries a few acres of shellfish under the debris. An underwater volcano erupts and parboils nearby fish. But nature had to create man to create, in turn, the devil's potion of pollution: oil spreading into the ocean from a stricken tanker; phosphates from washday detergents leaching into the estuaries; phenol and cyanide escaping from industrial processing plants; waste-laden effluents pouring from some sewage treatment plants poorly designed or badly operated.

Pollutants are resources where they do not belong. *Pollution* is an undesirable change in the characteristics of the air, land, or water that is harmful to human life and living conditions, or to the life of other desirable species. It occurs when we dump the residues of things we make or use, the pollutants, into the environment.

In this chapter, we concentrate on the pollution of our coastal zones. We recognize that this is only one aspect of the problem, which is remindful of the thermodynamic equation that states that the energy going into a system equals the energy leaving a system. So, too, the products of industry and agriculture, and the energies entering, say, an urban area are equal to the wastes leaving that area. To get rid of these wastes, we pour them into the passing estuaries; or burn them so that the winds carry them away, or perhaps let them hang as smog over the city; or bury them or lay them on the land. We do not consume these products and energies, only use them.

Because we emphasize here the problems of disposing of the wastes through the Nation's waterways, we are not in any way suggesting that it is preferable to dispose of them into the air or on the land. If choices must be made, then we suggest that they be studied carefully and related to the short-term and long-term anticipated uses of the environment and the effects of the pollutants on these uses. The ideal solution would be to have a self-contained system within an urban area wherein the wastes are recycled to yield usable products.

Figure 1. *Where they are needed most, many beaches in urban areas are closed or restricted because of pollution. (Federal Water Pollution Control Administration photo)*

I. BACKGROUND FOR CRISIS

Pollution gains strength from increasing population and increasing industrialization, and flourishes under inadequate management of the natural environment.

The Nation would be playing a fool's game if it expected that acts of Congress or improvements in technology, no matter how imaginative, would be able to clean up the pollution left by a population that increases without end. We agree with Stewart L. Udall when he says, "No comprehensive policy of our environment can fail to include recognition of the hazards of irresponsible population growth. The Federal Government has for too long resisted involvement in this central issue."[1]

If this issue is not addressed in time, then the people of the Nation, like bacteria in a petri dish, will continue to multiply until they are poisoned by their own wastes. However, the dominant factor is not the expanding population but the expanding economy. Industrial pollution is increasing at 4.5 per cent a year, or three times as fast as the population.[2]

[1]Remarks of Stewart L. Udall, Secretary of the Interior, before the Joint House-Senate Colloquium on National Policy for the Environment, July 17, 1968.

[2]Federal Water Pollution Control Administration, U.S. Department of the Interior, *The Cost of Clean Water,* 1968, Vol. 1, p. 20.

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We can gauge the size of the water pollution problem by considering the relation between the amount of fresh water available in the Nation and the amount needed to carry away its wastes. The amount of fresh water that flows from the continental United States and discharges into the oceans does not vary its total much and averages out at about 1,100 billion gallons a day. It is estimated that in 1954 about 300 billion gallons of the total available supply of water were withdrawn daily; of this amount, 190 billion gallons were used to return wastes to the streams. It is further estimated that at the end of this century, nearly 750 billion gallons of water will be needed to carry away our population's wastes. At that time, the Nation will be withdrawing a little more than 80 per cent of its total flow of fresh water, and will be contaminating with polluted returns about two-thirds of the total flow.[3] The Ancient Mariner's lament, "Water, water everywhere, but not a drop to drink," could have greater relevance to modern society than Samuel Coleridge could ever have dreamt.

Predictably, pollution and its effects are felt most strongly and do the most damage in our estuaries and Great Lakes. One reason is that populations tend to cluster in these zones. Another is that these areas are the most valuable portions of our marine environment and also the most vulnerable to pollution. The hydrological and geological characteristics of estuaries make these waters a sink for the non-degrading wastes flowing in the river basins.

Of the world's 10 largest metropolitan areas, 7 have developed on major estuaries. Today, 70 per cent of our Nation's population lives within one hour's drive of an estuary, ocean or the Great Lakes. Their personal and industrial wastes, treated and untreated, pour into these waterways.

Almost as important as the existence of water itself within the coastal zone is the quality of the water. Since the same water is often called upon to serve more and more masters, plans for shared use must be carefully laid, and compromises introduced in order to permit desired competing uses to coexist. For example, harbors and healthy oysters can coexist if pollution levels are held down; similarly, properly designed sewage treatment plants and a swimming area can coexist in the same area. Water quality is the common denominator for the shared or multiple-use concept.

[3]National Academy of Sciences-National Research Council, *Waste Management and Control*, 1966, p. 12.

II. TYPES OF POLLUTANTS

To reduce the study of pollution, its causes and effects to a manageable form, the National Academy of Sciences-National Research Council broadly classifies pollutants entering watercourses in eight categories:[4]

1) Domestic sewage and other oxygen-demanding wastes. *Ordinarily these wastes are reduced to stable compounds through the action of aerobic bacteria that require and obtain oxygen from the water. At excessive residue levels, the resultant oxygen reduction can have a serious impact on the life in the water. The oxygen-demanding fraction of domestic and industrial waste is growing much more rapidly than the efficiency of waste treatment, so that by 1980, it is estimated, the oxygen demand of treated effluents will be great enough to consume the entire oxygen content of a volume of water equal to the dry-weather flow of all of the United States' 22 river basins.*

2) Infectious agents. *Although modern disinfection techniques have greatly reduced the dangers from disease-causing organisms in water, incomplete elimination of these agents from sewage and domestic water supplies poses a continuing health hazard.*

3) Plant nutrients. *Growth of aquatic plant life is directly related to the availability of mineral*

[4]*Ibid.*

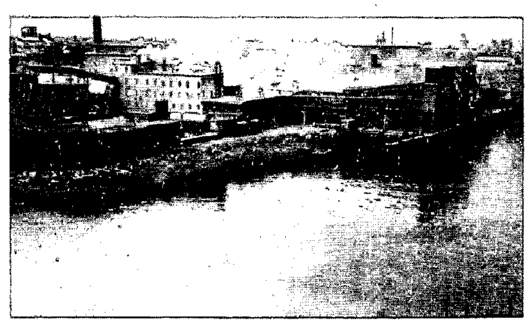

Figure 2. *Industrial wastes are a major source of water pollution. Besides blocking recreation access to the waterfront, obsolete industrial plants contribute to the total pollution problem: water, air, and land. (U.S. Coast Guard photo)*

substances in solution–particularly nitrates and phosphates. Such minerals are a normal constituent of land drainage and are also present in highly concentrated form in domestic, industrial, and agricultural wastes returned to streams. Problems from algae blooms and excessive plant growth are increasingly troublesome in many of the nation's major lakes and effective remedial measures are largely lacking.

4) Organic chemicals such as insecticides, pesticides, and detergents. *These substances are highly toxic at very low concentrations. They have caused spectacular kills of fish and wildlife. Of particular concern is our lack of knowledge of the effects of long-term and sublethal exposure. At present, prospects appear poor for developing methods either of effective treatment or of removal of the substances from water supplies.*

5) Other minerals and chemicals. *Included in this group of industrial wastes are chemical residues, petrochemicals, salts, acids, silts, and sludges. Some 400-500 new such chemical substances are created for use each year. Many are known to be toxic although full knowledge of their exact biological effects is lacking. Methods of removal are poorly developed.*

6) Sediments from land erosion. *Settleable and suspended solids resulting from land erosion fill stream channels and reservoirs, necessitate expensive additional treatment of water supplies, reduce a stream's ability to assimilate oxygen-demanding wastes, blanket fish nests and food organisms and tend to mask out the light required by aquatic plants.*

7) Radioactive substances. *Intense public concern has led to the successful development of techniques to prevent contamination under present conditions. The anticipated large increase in nuclear power reactors by the year 2000 poses a serious additional challenge, however.*

8) Heat from power and industrial plants. *Since the amount of dissolved oxygen that water can contain decreases with increasing water temperature, introducing heat into a stream has an effect equivalent to that of introducing oxygen consuming waste.*

III. POLLUTION PRESSURES

Even as we write, pressures continue to mount, which increase the pollution problem. Some of these noted in chapters 2 and 3 include:

–Rapidly increasing population. The demand for water within the next 50 to 60 years will triple while the population doubles. The increased per capita use of water will be caused by increased urbanization and industrialization; rising levels of income; and increased leisure and outdoor recreation. Rising demand also involves requirements for higher quality water than we have today.

–Greater mining of sand and gravel and possibly phosphates from off-shore locations. As we indicated earlier (Chapter 2), although there are ample land-based deposits of sand and gravel for construction purposes, the cost of carrying these deposits to urban areas is high. In addition, the movement to "Keep America Beautiful" is tending to close down some of the sand and gravel pits near large cities. Consequently, off-shore deposits of these materials have become very attractive when they are close to metropolitan areas.

–Increased desalting of estuarine and coastal waters as technology improves, creating brine, heat and radioactive waste disposal problems.

–Increased housing and commercial sites in estuaries, causing filling-in of marshes and bays, runoff of urban debris, and soil erosion. Commercial and private housing development was marked as the second major cause of the loss of estuarine areas;

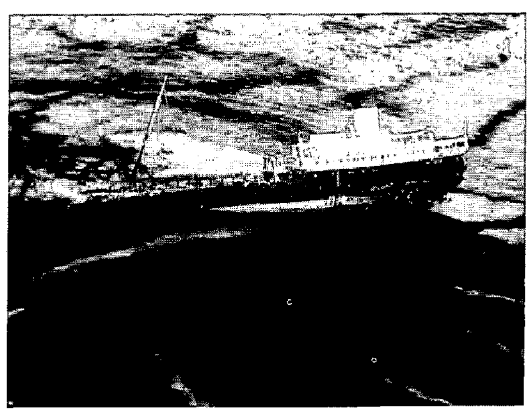

Figure 3. *Massive oil spills from the tanker* Ocean Eagle *off San Juan, Puerto Rico. (U.S. Coast Guard photo)*

by 1975, such developments will be the chief cause.

–Increased volumes of pollutants such as pesticides, lead oxide from automobile exhausts, and other industrial and agricultural wastes, most of which eventually end up in the Nation's coastal zones.

–Increased recreational demands, resulting in more channel dredging for marinas, and small-boat harbors, shoreline modification for beach stabilization, and pollutants from recreational vessels. The recreation industry is one of the fastest growing in the Nation and the recreation needs are growing much more rapidly than the population.

–Increased dredging for larger and deeper ports and harbors, with accompanying loads of spoil. Dredging activities do not necessarily pose major pollution problems, although all dredging increases water turbidity and hence has some ecological effects. However, the major pollution problem with dredging is when the spoil itself is polluted. Once it is stirred up or deposited in other water areas, its effects are obviously spread.

Lake Michigan currently is having problems stemming from the deposit of polluted dredged material. This was brought out during a conference held in Chicago early in 1968 composed of officials of the Federal Government and the four States bordering on Lake Michigan. The officials recognized that "the maintenance of waterways for commercial and navigational use is a constantly necessary activity." They concluded, however, that "the continued deposition of dredged material containing nutrients, oil, and solids of sewage and industrial wastes in Lake Michigan poses a distinct threat to the quality of the lake."

The Corps of Engineers agrees that wherever practicable and as soon as practical dredge disposal methods should be modified so that they will not unreasonably accentuate the water pollution problem.

–More and bigger nuclear-fired electric power plants located on the shorelines in order to obtain large quantities of cooling water. Electric power production in this Nation has doubled during every decade since World War II. Nuclear-fired power plants, with their lower Rankine efficiency and therefore higher unit heat loss than fossil-fueled power plants, are expected to supply about half of the new generating capacity between now and 1975. It is estimated that, by 1980, the power industry will use one-fifth of the total fresh water runoff of the United States for cooling.

The thermal effects of placing power plants along an estuary or a coastline have yet to be fully investigated. The temperature of the cooling water leaving a power plant is about 15-25° higher than when it enters. This thermal shock is lethal to a variety of marine animals, particularly in their larval stages. In addition, higher water temperatures produce heavier growths of aquatic algae and vegetation that are often undesirable. Such ecological changes can prevent the production of game fish and other species, resulting in their eventual elimination. High temperatures may not only be lethal but also may be a barrier to necessary movement of migrant species of fish.

Figure 4. *Although massive oil spills are disastrous and must be controlled, a greater problem exists in smaller chronic spills from passing ships and loading piers, rendering many beaches continually unfit for use. (photo by Kirk Reid)*

–Oil pollution and pollution from other hazardous materials. Pollution of the marine environment through massive oil spills has received increasing public notice because of several recent dramatic situations involving damaged tankers. These occurrences highlighted the ease with which natural resources and the economic life dependent upon them could be wiped out by one unfortunate incident, and focused attention on the possibility of other such incidences. Yet the most pervasive pollution comes not from headlined oil spills but from the many activities that take place every day underwater. There are about 16,000 oil wells off the continental United States, and the number is increasing by more than one thousand a year. There is rightful concern that oil well blow-outs, leaks in pipelines, and storm damage can cause pollution that could ruin large parts of commercial fisheries, sportsfishing, and recreational areas.

The extent of the oil pollution problem is intimately connected to the fact that nearly a billion barrels of oil a year are carried along the 90,000 miles of U.S. coastline and enter this Nation's ports. A Congressional committee found that

of the various threats to our environment from oil pollution, the most serious occurs during transport of oil. This includes movement, loading, unloading, transfer, and cleanup. It includes bulk movement by vessel, river, and lake barge, pipelines, road and rail tank cars, terminals, pump stations, and bulk marketing. Accidents, poor maintenance, carelessness, shortcutting of cleanup operations, the apparatus and the methods used—all contribute to the problem.[5]

The immediate need is to stem the heavy damage to the Nation's resources arising from the 2,000 or more spills of oil and other hazardous materials that occur each year in U.S. waterways.

The Administration took a commendable step toward solving this problem when it formulated the National Multi-Agency Contingency Plan last fall.[6] This panel endorses the concept of the Government reacting quickly and expeditiously to stem the deleterious effects of an oil spill, as detailed in the Plan. We believe, though, that its creators were restrained by lack of sufficient legal authority to assign fiscal responsibility to those agents, land-based or sea-based, responsible for acts leading to pollution of our waters by oil or similarly hazardous material. We endorse legislative efforts to assign such fiscal responsibility to the owners and operators of offending vessels and installations, sea- and shore-based.

One practical problem in assigning financial responsibility is that the effects of pollution may go on and on with no end to the legal liability of the polluters. Insurance companies are loath to underwrite policies to cover all contingencies. This

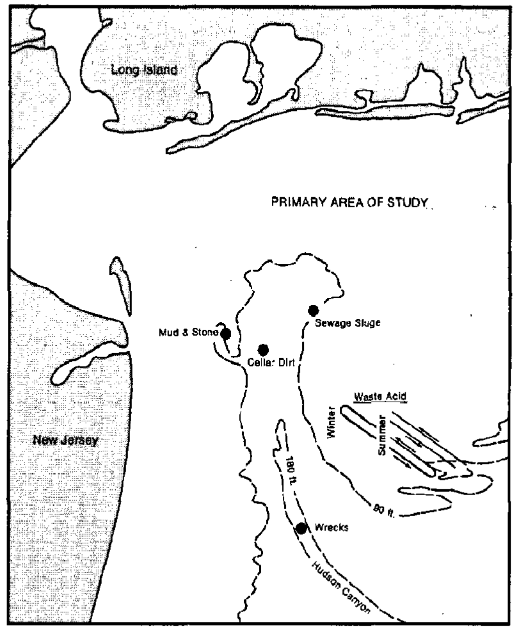

Figure 5. *Waste dumping areas off New York. More must be learned about the effects of dumping wastes at sea.*

panel believes that there should be appropriate limitations to a polluter's liability. However, the liability should be high enough to effectively deter potential polluters, and to cover much if not all of the cleanup—but not so high as to make insurance unavailable.

IV. FEDERAL ACTS, ORDERS, AND AGREEMENTS

Federal interest in water pollution dates back many years, the first major effort occurring with the Oil Pollution Act of 1924.[7] However, the intense public interest in pollution is a relatively new phenomenon. Congress has responded by creating the Federal Water Pollution Control Administration through legislation passed in 1965. A year later Congress passed additional water pollution control legislation. Both pieces passed without a single dissenting vote, thereby underscoring Congress' interest in clean water. This goal was further stated by the President in Executive Order 11288, signed July 2, 1966.

The Water Quality Act of 1965, one of the two recent amendments to the Federal Water Pollution

[5] Federal Water Pollution Control Act Amendments of 1967, Report of the Committee on Public Works, U.S. Senate, Report No. 917, Dec. 11, 1967.

[6] National Multi-Agency Oil and Hazardous Materials Contingency Plan, September 1968.

[7] 33 U.S.C. 431 *et seq.* This Act prohibits the discharge of oil from any boat or vessel into navigable waters of the United States or upon the shoreline.

Control Act,[8] contains a requirement of historic significance—that water quality standards for interstate waters be set by the States, and then be approved as Federal standards by the Secretary of the Interior. Congress defined "interstate waters" to include all coastal waters. *Coastal waters* are those waters affected by the ebb and flow of the tide and clearly include estuaries.[9]

All States, the District of Columbia, Puerto Rico, and the Virgin Islands have submitted water quality standards. By the middle of 1968, most had been approved as Federal standards. The remainder were under review by the Department of the Interior.

The standards identify uses of the waters, including agricultural, municipal, industrial, recreational, fishery and wildlife. They indicate the water quality necessary to support each use, and include plans to implement and enforce this quality.

The Nation does not yet have enough experience to know whether the Water Quality Act of 1965 will be effective in protecting and enhancing the waters of its coastal zone. Suggestions have been made that the Secretary of the Interior be given authority to seek court action against potential polluters. We feel that such authority would not necessarily be more effective than the means that the States and Federal Water Pollution Control Administration already have. Moreover, awarding such authority would be premature since time must be given to test and appraise adequately the effectiveness and enforcement of the water quality standards.

Through effective State-Federal relationships in carrying out the provisions of the Water Pollution Control Act, we see a powerful instrument for fashioning a healthy coastal zone system. The intent of this act would be further abetted if public hearings were called prior to any action that would appear to affect significantly the water quality of the coastal zone. Such public hearings are now required only if standards are to be changed. If after sufficient experience the Nation finds that the water quality of its coastal zone is nonetheless being unacceptably degraded, then additional executive and legislative action will be needed.

Each State, having set its water quality standards, has the responsibility to monitor the waters to which these standards apply and enforce their application.

The Nation should know how well this program is proceeding. Therefore, this panel recommends that the Secretary of the Interior prepare a biennial report of the pollution level of each of the Nation's estuaries and how it relates to the progress the various States are making in their pollution abatement programs under the Water Quality Act of 1965. Data for the inventory should be gathered by the individual States with the cooperation and support of the Federal Government.

Long-range water quality planning is clearly essential (1) to satisfy the needs of local communities, States, and the Nation, (2) to allocate

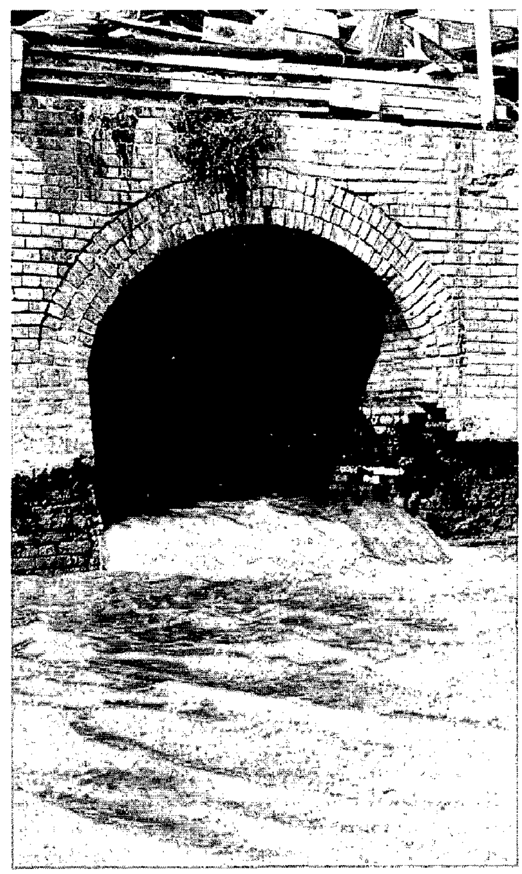

Figure 6. *"Combined" storm sewers are a major source of water pollution by municipal sewage. (Federal Water Pollution Control Administration photo)*

[8] 33 U.S.C. 466.

[9] Contained in memorandum of June 13, 1966, to Commissioner, Federal Water Pollution Control Administration from Solicitor, U.S. Department of the Interior, Interior Memo No. M-36690.

effectively the energies and money to reach these ends, and (3) to realize them expeditiously. We therefore suggest that States look ahead 10-20 years and enunciate their long-range plans and priorities for the water quality of their coastal zones. In turn, the Federal Government should use these programs and priorities as guides to rank Federal priorities and assign funds to States.

The second of the recent amendments to the Federal Water Pollution Control Act, the Clean Water Restoration Act of 1966, authorized $3.4 billion in Federal grants to municipalities over a four-year period to help build sewage treatment plants and interceptor sewers. This money is intended to help remove the backlog of construction of waste treatment plants and to help keep pace with the need for new construction created by increased population and output of effluents.

On a cost-sharing basis with municipalities and the States, the money would buy about $8 billion of construction. However, Congressional appropriations have lagged authorizations. Starting in FY 1968, the annual authorized funds are as follows: $450 million, $700 million, $1 billion, and $1.25 billion. But the appropriation for FY 1968 was only $203 million, and for FY 1969 only $214 million. In other words, about $1.7 billion of municipal waste treatment plants and sewers envisioned in 1966 will not be constructed within the time originally anticipated. We urge that funds for waste treatment works be appropriated at authorized levels in the remaining two fiscal years.

A. Unclear Authority

In the face of the Nation's clean water goal, some Federal agencies have unclear or insufficient pollution control authority to carry out the Nation's desires.

The Army Corps of Engineers has probably affected the shape and ecology of many of the Nation's estuaries and much of its coastline to a greater extent than any other Federal agency. The Corps' influence stems from the Corps' own dredging activities in addition to its power to grant or deny permits for dredging and filling navigable waters, an authority based on the Rivers and Harbors Act of 1899.[10]

When that Act was passed, commerce and not pollution attracted National attention. Thus, the Act is concerned solely with the navigational aspects of waterways. More recent Federal regulations appear to give the Corps the added responsibility of preventing undue destruction of the resource-rich estuaries. Literature of the Corps states:

The determination as to whether a permit will be issued will be based on an evaluation of all relevant factors including the effect of proposed work on navigation, fish and wildlife, conservation, pollution, and the general public interest. The Corps will accept comments on these factors, which will be made part of the record and will be considered in determining whether it will be in the best public interest to grant a permit.[11]

Yet whether the Corps can deny an applicant a permit on any basis except navigation has not yet been fully tested in court.[12]

Several regulations purport to affect the granting of Corps' permits for reasons other than navigation. One of these stems from the Fish and Wildlife Coordination Act.[13] This was amended in 1958 to require the Corps, and any other private or public agency needing Federal permission to alter the course of any body of water, or physically change it even for a navigation or drainage end, to consult both with the Fish and Wildlife Service of the Department of the Interior, and with the Wildlife Resources Office of the affected State. The Act requires that the recommendations of both these resource agencies regarding the wildlife aspect of the project be explicitly considered in the planning.

The second influence on the Corps resides in an agreement[14] between the Corps and the Department of the Interior, signed in 1967, in which there was a declared policy to combat pollution in dredg-

[10] Act of March 3, 1899, 30 Stat. 1121, 33 U.S.C. 407, ch. 425.

[11] Office of the Chief of Engineers, Department of the Army, *Civil Regulatory Functions,* ER1145-2-303, section 4d.

[12] *Zabel* v. *Tabb,* No. 67-200, Civ-T, Middle District, Florida, Mar. 14, 1968. See discussion of this case in Chapter 8.

[13] Act of March 30, 1934, 48 Stat. 401, 16 U.S.C. 666c, ch. 55.

[14] Memorandum of Understanding between the Secretary of the Interior and the Secretary of the Army, July 13, 1967.

Figure 7. *At the present rate it is estimated that by the year 2000, man will be using and contaminating more than two-thirds of the Nation's fresh water flow. (Bureau of Sport Fisheries and Wildlife photo by M. Fahay)*

ing, filling, or excavation of U.S. navigable waters. As a result of this agreement, field representatives of the Corps and of the Department of the Interior confer before the Corps decides whether to grant a permit affecting any navigable water.

There is a fundamental weakness in a procedure that attempts to persuade the Corps that factors other than navigational ones should be considered in its permit-granting activities but, at the same time, does not give the Corps the needed clear authority to act on these considerations.

B. Insufficient Authority

Some Federal agencies seemingly have no authority to consider the effects of their activities upon water pollution. For example, the Atomic Energy Commission issues licenses for nuclear power plants whose waste heat could seriously pollute coastal zones. Yet this agency is not held accountable for such thermal pollution.

Executive Order 11288,[15] issued by President Johnson in July 1966, provided encouragement and direction for pollution control but is not a source of new authority. The Order insists that all Federal polluters take corrective action. Further, the Order requires water quality to be an important consideration in all planning and construction and operation of new Federal activities, building and water resources projects, including additions and rehabilitation. The Order also commits the Federal establishment to what the States are requiring of their cities—secondary treatment of all wastes.

The AEC has stated that Executive Order 11288 does not enlarge the agency's authority to permit consideration of thermal pollution. The Department of Justice agrees with this view and says:

It is evident that Section 7 [aimed at controlling water pollution stemming from activities using Federal loans, grants or contracts] is not intended as an independent source of agency authority, but rather a direction to the several agencies to consider using such authority as they . . . have . . .[16]

The Department of Justice also ruled out Section 11 of the Federal Water Pollution Control Act[17] as authority for the AEC to consider thermal pollution. This section directs Federal agencies with "jurisdiction over any building, installation or other property" to prevent or control water pollution. This, the Justice Department says, means proprietary jurisdiction, not regulatory jurisdiction.

In view of the instances of unclear or nonexistent Federal authority to deal with water pollution control problems, this panel suggests that Federal agencies having responsibilities in the Nation's coastal zone also have a responsibility to see that their work and programs fully meet water quality goals. The panel therefore recommends that each Federal agency having such programs or sponsoring such programs be assured prior to approving them that they will not frustrate water quality goals. If the programs do, then this

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[15] F.R. Doc. 66-7460, filed July 5, 1966.

[16] Letter from Department of Justice to General Counsel of AEC, April 25, 1968.

[17] *Ibid.*

circumstance should be a sufficient condition for discontinuing them or withholding Federal support. Moreover, Federal contracts, loans, grants, leases, licenses and permits should require their holders to conform with water quality standards.

If an agency does not have the authority for the above actions, it should be given in appropriate legislation.

This panel notes that Section 7 of Executive Order 11288 has in general been used with great timidity by the various Federal agencies. We urge these agencies to use more aggressively the powers given them under this Order and other authorities. Holders of Federal grants, loans, contracts and other devices certainly can be called upon to arrange their activities to conform with State water quality standards. And there is obvious precedent for effective provisions to be included in Federal instruments to help attain various National goals. This is evidenced by the minimum wage provisions called for in the Davis-Bacon Act and with the civil rights provisions that have become standard in Federal contracts.

V. PRIORITIES IN WASTE MANAGEMENT

Solutions to the pollution problem require consideration of factors well beyond the charge of this Commission. We agree with others who have considered this problem that prevention is more effective than abatement. The best solution to pesticides finding their way into our Nation's streams is not to devise a method of removing them from the water, but to develop degradable and less lethal pesticides, better controls on their use, and, ultimately, alternative methods of insect control that will not contaminate our environment.

Figure 8. *A dump at a Navy installation at Indianhead, Maryland. An often overlooked Presidential Order directs Federal agencies to comply with the goals of water pollution control. (National Park Service photo)*

Prevention of pollution is accomplished in one of two ways: first, and most effective, by reducing the generation of wastes initially; second, by treating wastes after they have occurred but before they enter public waterways. Treatment may be at the source of the pollutants or at some collection point located before the disposal point.

A third alternative in waste management—managing wastes in the waterways through streamflow regulation, natural assimilation, dispersion of wastes and other techniques—is classified as cleanup of pollution after it has occurred.

At present our private economy is geared toward getting goods to the consumer. But, unfortunately, the consumer consumes very little. At most, he transforms it. This panel is of the opinion that this Nation must develop a program which places sufficient responsibility on the producer, whether it is the producer of insecticides or plastic bottles, to consider the consequences of retrieving his goods once they have reached the consumer.

The first impulse of municipalities and industry is to use the natural assimilative powers of the waterways that flow nearby to process pollutants. This procedure has the advantage of initial economy and the backing of tradition. Moreover, there is no way to escape the fact that the coastal zone will have to absorb some pollutants. This leads us to the conclusion that we must preserve as much of the assimilative powers of these waterways as we can because population and industrial growth alone will of necessity impose greater demands on them. Even treatments that remove 95 per cent of the pollutants in waste water leave 5 per cent to be assimilated, still a very large amount. The assimilative powers of the coastal zone must also be preserved to take care of non-point-source pollutants, and pollutants generated by natural and man-made emergency situations such as hurricanes or inadvertent dumping of toxic materials into coastal waters.

Pollutants whose origins are not easily traced, the "non-point-source" pollutants, are often introduced by agricultural runoffs of fertilizers and pesticides, watercraft discharges, acid mine drainage, storm runoffs from city streets, and runoffs from animal feed lots.

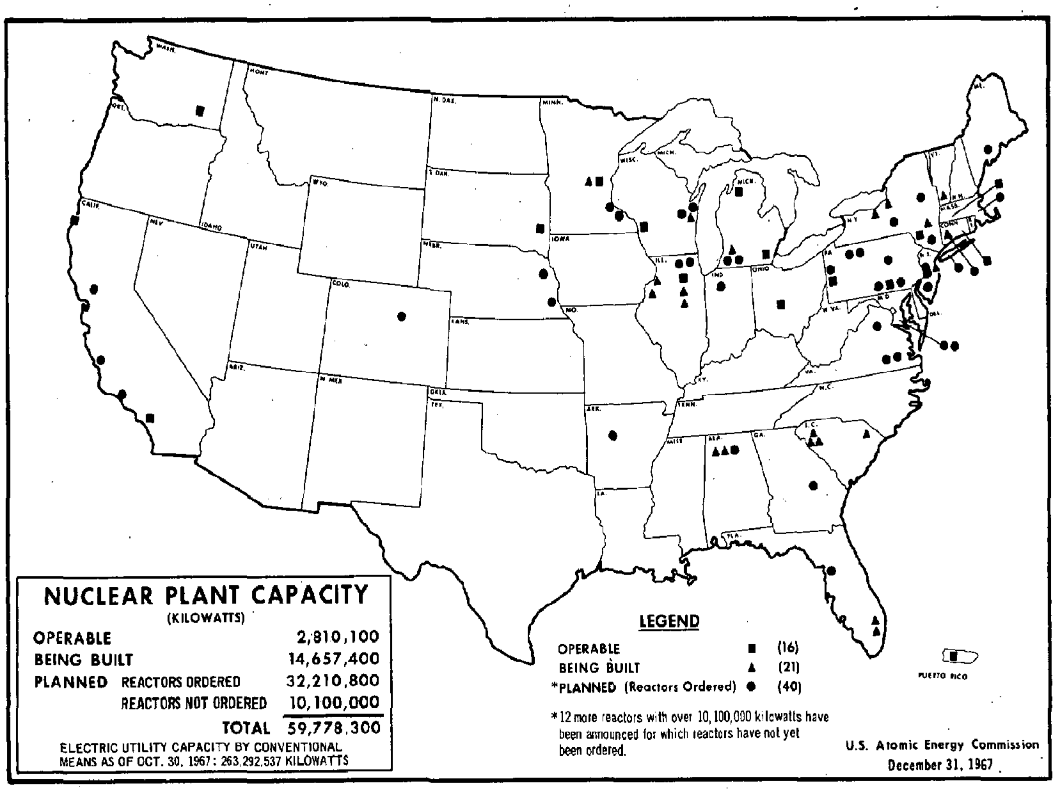

Figure 9. *Existing and planned nuclear power plants. (Source: Atomic Energy Commission)*

To help preserve the assimilative powers of the waterways, industry should be encouraged to reduce or recycle its waste products. Production systems and equipment supporting them should be designed with this in view.

Many waste-treatment plants are not working at maximum efficiency because unskilled or untrained personnel operate them. Responsible governmental agencies should help train and require certification of operators of waste-treatment plants. If this action is to be fully effective, it should be coupled with adequate staffing and pay scales within the plants.

VI. COST OF WASTE TREATMENT

The price the Nation will have to pay to assure itself of adequate waste treatment systems was recently reported on in a Department of the Interior study.[18]

It essentially covers the five-year period from 1969 to 1973 for projecting its costs. The costs given are based on waste treatment plants processing various point-source pollutants to meet the water quality standards established through Federal legislation. Costs are expressed in "constant 1968 dollars":[19]

–The cost of constructing municipal waste treatment plants and interceptor sewers is estimated at $8 billion, exclusive of land and associated costs... By 1973 the urban population required to be served will comprise about 75% of the total U.S. population... Currently, [the wastes of] only 55% of the urban population is receiving adequate treatment. It is estimated that, to meet water quality standards by 1973, [the wastes of] 90% of the urban population will require secondary treatment, and 10% primary treatment.

–There may be significant opportunities for reducing the costs, as well as for contributing to more effective pollution control, through establishment of intermunicipal sewage treatment and disposal systems and districts. In many cases, however, it will be necessary to overcome the existing institutional obstacles to develop effective arrangements for such systems.

–Operation and maintenance costs for the required treatment works are estimated at $1.4 billion for the five-year priod. Unlike annual construction costs, which can be expected to level off after the initial backlog has been eliminated, operation and maintenance costs will continue to rise as more sewage treatment plants are placed into operation.

–Construction of sanitary collection sewers will require an estimated $6.2 billion over the next five years. These costs will be an integral part of necessary expenditures for waste disposal by the communities involved.

We note that the Senate Public Works Committee has indicated in one of its reports that the total cost may be much higher than stated in the Interior study, amounting to "at least $20 billion" to meet the cost of waste treatment plant construction needs by 1972.[20] The Committee's view is probably closer to the truth. Interior notes that its study does not take into account the cost of sanitary collection sewers or processing the more difficult pollutants.

Manufacturing remains the chief source of controllable waterborne wastes. In terms of quantity of waste water discharged, and the standard biochemical oxygen demand, wastes from manufacturing establishments are about three times as great as those from the Nation's sewered population.[21] Moreover, as we noted earlier, the volume of industrial production that gives rise to industrial wastes is increasing at about 4.5 per cent a year, three times as fast as the population.

Estimates from the *Cost of Clean Water* study indicate that the minimum investment for plant and equipment to attain water quality standards by fiscal 1973 for major water-using industrial establishments is in the $2.6 to $4.6 billion range. If the estimates include operating expenses and also the charges for restoring thermal discharges to stream temperatures, then the total industrial cost rises to between $8.3 and $10.7 billion for pollution control for the five-year period.

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[18] Federal Water Pollution Control Administration.

[19] *Ibid.*, Vol. 1, p. 3ff.

[20] *Steps Toward Clean Water,* report to the Committee on Public Works, U.S. Senate, from the Subcommittee on Air and Water Pollution, January 1966, p. 3.

[21] Federal Water Pollution Control Administration, Vol. 1, p. 20.

These estimates are based on the assumption the industries generally will have to provide a level of treatment of industrial wastes at least equivalent to secondary treatment of municipal wastes.

VII. FUTURE TRENDS

We must look ahead to see how well secondary sewage treatment will be serving us over the next several decades. We must see if need for waste treatment goes beyond the secondary stage now proposed in the water quality standards. It will not be surprising to find after significantly decreasing or removing point sources of pollution that the non-point sources will be credited with having brought us the most grief.

Our last defense against pollution is to clean it up after it has occurred. No matter how well we plan, accidents will occur as witness the Torrey Canyon and Ocean Eagle oil spills. The number of such accidents may or may not decrease in the future, but the potential danger of a single accident whether it be an oil tanker, an industrial plant, or a nuclear power plant will increase. It is important that we develop better methods for responding to these accidents. It is hoped that the proposed National Contingency Plan will be adequate for the task.

One activity that concerns this panel is the use of ocean outfalls and waste disposal at sea. The ocean is treated as an infinite sink in its ability to absorb wastes, just as our land-contiguous waters were until very recently.

Ocean outfalls are used extensively in California and, in some instances, have prevented disastrous pollution of estuarine areas. Very little is known about the ecological effects of ocean outfalls and waste disposal at sea. California is starting to examine this problem from the point of view of the San Francisco Bay-Delta water quality control program.[22]

This panel feels that responsible Government agencies should take immediate steps to learn the effects of ocean outfalls and waste disposal at sea.

[22]Raymond Walsh, "San Francisco Bay-Delta Water Quality Control Program," *Journal of the Water Pollution Control Federation,* p. 241.

I. BACKGROUND OF FEDERAL POLICY

The material in this chapter comes from a report of the same title by the U.S. Army Corps of Engineers. The Corps of Engineers, through the Rivers and Harbors Acts, has the basic statutory responsibility for the planning, development, and maintenance of the Nation's navigable waterways and harbors. The material has been made available through the courtesy of the Director of Civil Works, Office of the Chief of Engineers, Department of the Army.

Since colonial times coastal harbors and channels, and later those on the Great Lakes, have played an important role in the Nation's commercial and industrial growth. Early settlers used harbors and coastal rivers as arteries for trade and opening new areas for settlement. Colonists cleared snags and other obstructions from segments of main coastal streams and constructed port facilities to accommodate trade with European countries.

National interest in and support of improved navigation facilities were evidenced even prior to establishment of the Union. In 1787, two years prior to adoption of the Constitution, the Northwest Ordinance was passed,[1] representing the first National declaration of navigation development policy. That Act declared inland navigable waters to be common highways and forever free.

[1] U.S.C.A. Constitution, Art. 1, §§ 1-9.

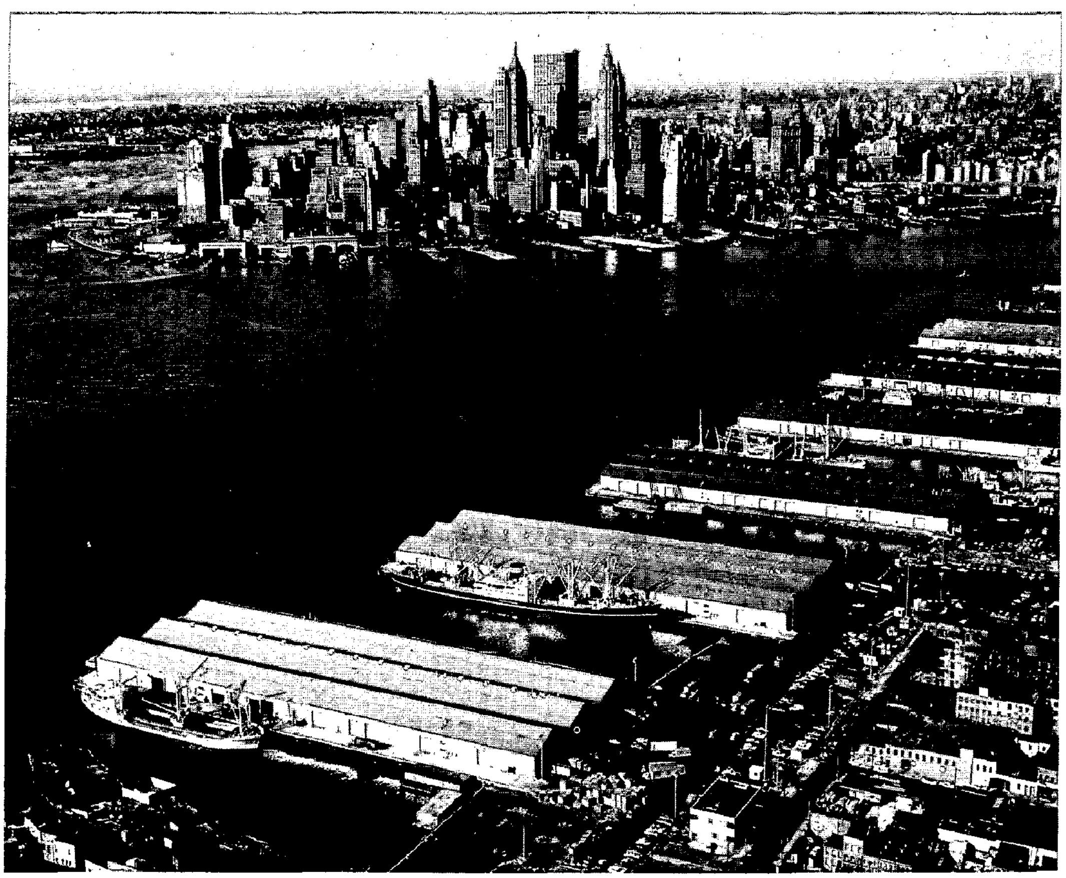

Figure 1. *Virtually every population and industrial center is also a major port. (Port of New York Authority photo)*

Framers of the Constitution sought to encourage interstate commerce by extending the concept of free use of navigable waters to include coastal harbors and entrance channels. The Commerce clause[2] of the Constitution delegated to Congress the power "to regulate commerce with foreign nations and among the several states" and stipulates "no preference shall be given by any regulation of commerce or revenue to the ports of one state over those of another; nor shall vessels bound to, or from, one state be obliged to enter, clear or pay duties to another."

During the earliest years of the Nation's history, Federal interest in navigation improvements tended to concentrate on inland requirements. This initial focus was appropriate, for, given the vessel technology of the time, coastal harbors in their natural conditions generally were adequate.

Even so, Federal investment in harbor and supporting facilities dates from 1789. In that year, Congress authorized the Treasury to assume the costs of lighthouses, beacons, buoys, and public piers which had been erected by the colonial governments.[3] In 1790, Congress authorized Federal maintenance of a then major shipping pier on the Kennebunk River, Maine. In 1802, Congress authorized expenditures of $30,000 for repair and reconstruction of public piers on the Delaware River.[4] In 1809, Congress requested an investigation of the Carondelet Canal between Lake Ponchartrain and the Mississippi River and, subject to a determination that work would be economically justified, authorized $25,000 for construction.[5] Formal determination of economic feasibility has been a major characteristic of the Federal harbor and channel improvement program since.

The Federal program for harbor and channel work largely followed a "natural" course. No attempt was made to initiate a formal, long-range program or schedule for harbor improvements. Rather, harbor and channel facilities were investigated and projects carried out in response to evolving economic and trade conditions, and to meet dispersed and relatively independent area needs.

[2]U.S. Constitution, Art. 1, Sec. 8, Cl. 3

[3]Act of August 7, 1789, Stat. 53.

[4]Act of April 6, 1802, 2 Stat. 152.

[5]Act of February 10, 1809, 2 Stat. 517.

Studies were assigned to the Army on an intermittent basis by Acts of Congress, either in the form of individual survey resolutions, or embodied in the River and Harbor Acts passed on a regular basis since 1826.

The principal Federal concern has been with the adequacy of harbor and channel facilities for commercial trade purposes. Investment in harbor and channel facilities has been aligned generally with and responsive to commodity movement trends and changing vessel technology. This means that while the Federal Government has assisted in the development of over 500 commercial harbors to date, very many have experienced a number of separate authorizations and incremental improvements. In all cases, authorization of improvements has depended upon a finding that the benefits—normally measured in terms of prospective reductions in shipping costs, which translate into widespread public benefits—are found to be greater than the cost of improvements.

If the benefit-cost analysis is favorable, the Government then bears the construction cost of commercial navigation facilities and also assumes responsibility for operation and maintenance (usually involving periodic dredging). The Government also provides necessary navigation aids, such as charting, channel markers, and buoys.

Since the Army's Civil Works program was initiated in 1824, the Corps of Engineers has conducted the improvement of harbors and connecting channels in all U.S. coastal regions and on the Great Lakes. Table 1 summarizes, by class of harbor and region, investments made between 1824 and 1966. The table shows that approximately $2.2 billion has been expended. Approximately 75 per cent, or $1.7 billion, has been for deep draft harbors and channels.[6] Nearly one-half of the deep draft investment has been for Atlantic Coast facilities. The remainder has been fairly evenly distributed between the Gulf, Pacific Coast, and Great Lakes areas.

As a result, depths of 35 feet now generally prevail at major harbors on the Atlantic and Gulf Coast, ranging up to 45 feet in portions of New York Harbor. Depths of 30 to 40 feet are generally available in principal Pacific Coast harbors. The

[6]Deep-draft is defined as authorized depth of 30 feet or greater for Coastal harbors, 15 feet or greater for Great Lakes harbors.

Table 1
SUMMARY OF FEDERAL INVESTMENTS IN COASTAL AND GREAT LAKES HARBORS, 1824-1966
(in thousands of dollars)

Class of Harbor	Construction Expenditures	Maintenance Expenditures	Total Expenditures	Non-Federal Cost[1]
	Expenditures through FY 1966			
Depth: Under 15 feet				
Atlantic coast . . .	31,108	17,539	48,647	13,081
Gulf coast	6,596	2,526	9,122	143
Great Lakes . . .	13,649	6,182	19,831	7,430
Pacific coast . . .	10,528	12,985	23,513	3,056
Subtotal	61,881	39,232	101,113	23,710
Depth: 15 to 20 feet				
Atlantic coast . . .	72,379	68,446	140,825	7,326
Gulf coast	11,687	24,550	36,237	3,299
Great Lakes . . .	178,794	93,062	271,856	22,177
Pacific coast . . .	41,730	45,018	86,748	27,967
Subtotal	304,590	231,076	535,666	60,769
Depth: 30 feet and over				
Atlantic coast . . .	420,810	406,275	827,085	29,624
Gulf coast	181,593	122,596	304,189	29,844
Great Lakes . . .	1,432	80	1,512	0
Pacific coast . . .	127,684	128,363	256,047	38,227
Subtotal	731,519	657,314	1,388,833	97,695
Related Investments[2]				
Atlantic coast . . .	23,147	5,665	28,812	2,579
Gulf coast	12,065	6,387	18,452	3,609
Great Lakes . . .	11,707	14,183	25,890	146
Pacific coast . . .	32,483	23,723	56,206	14,215
Subtotal	79,402	49,958	129,360	20,579
GRAND TOTAL .	1,177,392	977,580	2,154,972	202,753

[1] Monetary value of local contribution identified in project authorization documents. Table 2 shows non-Federal investments in harbor and port facilities beyond that required for the authorized project.
[2] Additional Federal construction items required to sustain functional utility of projects, but not incorporated in basic project.

27-foot depth of the St. Lawrence Seaway controls the Great Lakes navigation system.

Beyond the Federal investment, other major expenditures have been required to achieve improved shipping technology and larger, more efficient cargo vessels. A harbor, basically, is only a sheltered water area affording a natural or artificial haven for ships. Only when adequate marine terminal facilities have been provided (including piers and wharfs; cranes and other mechanical handling equipment; transit sheds, warehouses and other storage areas; and service roadways and railroad tracks) does a harbor become a part of a functioning port.

Provision of these latter facilities has always been a non-Federal responsibility. Additionally, non-Federal interests have been required to provide the necessary lands, easements, and rights-of-way; spoil disposal areas; necessary alterations to or relocations of utilities; a share of the cost of bridge modifications; and the necessary dredging for vessel berthing areas. Table 1 also shows the

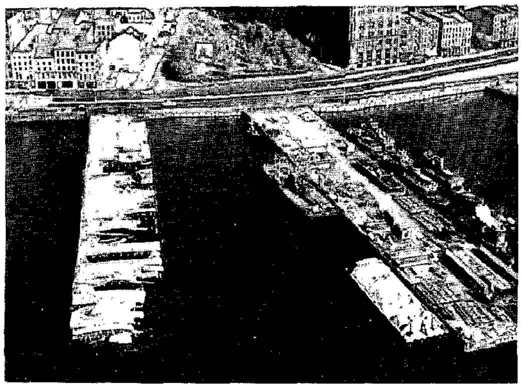

Figure 2. *Major existing port facilities are obsolete or abandoned. (Port of New York Authority photo)*

monetary value of non-Federal contributions to Federally-sponsored harbor and channel projects.

While full historical information on non-Federal investment in other terminal and cargo handling facilities beyond that required as part of the project is not complete, figures compiled by the Maritime Administration for the 20-year period 1946 to 1965 show additional facility investment within ports totaling at least $2.025 billion (see Table 2). Clearly, port development has required substantial financial commitment from both the Federal and non-Federal sectors.

Table 2

PORT DEVELOPMENT EXPENDITURE IN THE UNITED STATES
Jan. 1, 1946, to Dec. 31, 1965
(in thousands of dollars)

Region	General Cargo Facilities	Specialized Facilities	Total
Atlantic Coast....	$ 627,852	$324,422	$ 952,274
Gulf Coast....	198,156	186,671	384,827
Great Lakes ...	82,116	168,612	250,728
Pacific Coast....	276,045	161,482	437,527
Total....	$1,184,169	$841,187	$2,025,356

Source: Maritime Administration.

In summary, while the larger and more essential vessels and streamlined shipping operations forecast for the future hold much promise for reducing the cost or improving the quality of transportation services, their realization cannot be automatically anticipated. Responsible exploitation of the supercarriers and container movement potential is highly dependent on adequate planning for and installation of basic support facilities. The planning effort promises to be no mean task, especially in light of complicating factors described in the following section.

II. PHYSICAL OBSTACLES TO HARBOR DEEPENING

Continued improvement of the Nation's harbors and channels and related terminal facilities is an obvious prerequisite to sustained economic growth. At this point in time, however, only one general observation appears valid: physical-cost factors associated with further harbor deepening, coupled with anticipated changes in cargo handling and marketing operations, is going to require that public (including Federal) and private managers choose between possible investment locales and technological alternatives. The choices probably will lead to a pattern of specialization in facilities, permitting more efficient accommodation of trade demands.

III. COMMODITY MOVEMENTS

The investment in harbor and port facilities has stimulated and supported a constantly increasing volume of traffic. The distribution of traffic, by commodity types and regions, and the vessels used in this distribution, will be primary determinants of future investment requirements. This section illustrates basic commodity movement patterns, identifies those most important to various regions, and forecasts vessel technology likely to influence future movements and harbor-port needs.

Total foreign and domestic waterborne commerce[7] at all coastal and Great Lakes harbors increased from 522 million tons in 1950[8] to about 800 million tons in 1965. This represents an average annual growth rate of 2.9 per cent. Most of the increase is related to foreign commerce, which grew at an annual rate of 6.7 per cent between 1950 and 1965, while domestic ship-

[7]Department of Army, Corps of Engineers, *Waterborne Commerce of the United States,* volumes for 1950 through 1965.

[8]The year 1950 was selected as the base year for two reasons: statistics before that time did not reflect the detailed commodity breakdowns presently used, and therefore are not comparable; and the post-World War II period marked the beginning of construction of the very large oceangoing vessels.

ments remained relatively stable during that period (See Figure 3). Foreign commerce accounted for 56 per cent of the total volume in 1965.

During 1950 to 1965, the bulk commodities of crude petroleum and petroleum products, ores, coal, and grain dominated the commercial deep draft tonnage. As shown in Figure 4, these commodities accounted for approximately 74 per cent of the total volume of commerce handled in coastal and Great Lakes harbors in 1965.

Preliminary forecasts indicate that total foreign oceanborne commerce passing through U.S. ports will increase from about 350 million tons in 1965 to over 1,250 million tons in the year 2000 (See Table 3). The forecasts show an increase of 73 per cent in demand for waterborne transportation in the liner trade;[9] irregular trade[10] will increase 371 per cent; and tanker trade will increase 184 per cent. Projections of foreign commerce on the Great Lakes, or domestic deep draft shipments, are not available at this time.

[9]Liner trade refers to liner (berth) service which is defined as a scheduled operation by a common carrier whose ships operate on a predetermined and fixed itinerary over a given route, at relatively regular intervals, and are advertised considerably before sailing in order to solicit cargo from the public.

[10]Irregular trade (service) is comprised of "tramp" and other types of service which do not conform to the criteria described for a common carrier in "liner" service. A "tramp" ship in traditional terms is one that operates on an irregular or unscheduled basis from one port of lading to one port of discharge. Irregular trade would generally include dry bulk shipments of ore, grain, coal, etc.

IV. TRENDS IN VESSEL SIZE AND IMPLICATIONS

While analyses of future commodity volumes require much more intensive treatment, continuing technologies point assuredly to changing means being employed for handling present as well as future volumes of commerce. Changing vessel technology alone will necessitate considerable investment in harbor and port development or redevelopment.

A. Petroleum Vessels

Growth in the cargo-carrying capacity of deep draft vessels has been steadily on the rise since World War II, and has shown an exceptionally significant increase during the past decade. In 1945, the standard size petroleum vessel was the 16,460 dead weight ton (dwt)[11] "T-2" tanker. In

[11]Dead weight ton identifies a ship's total carrying capacity including internal provisions, at salt water, summer load line immersion. Actual cargo capacity is slightly less. For example, a 50,000 dwt tanker can carry about 47,000 tons of crude petroleum.

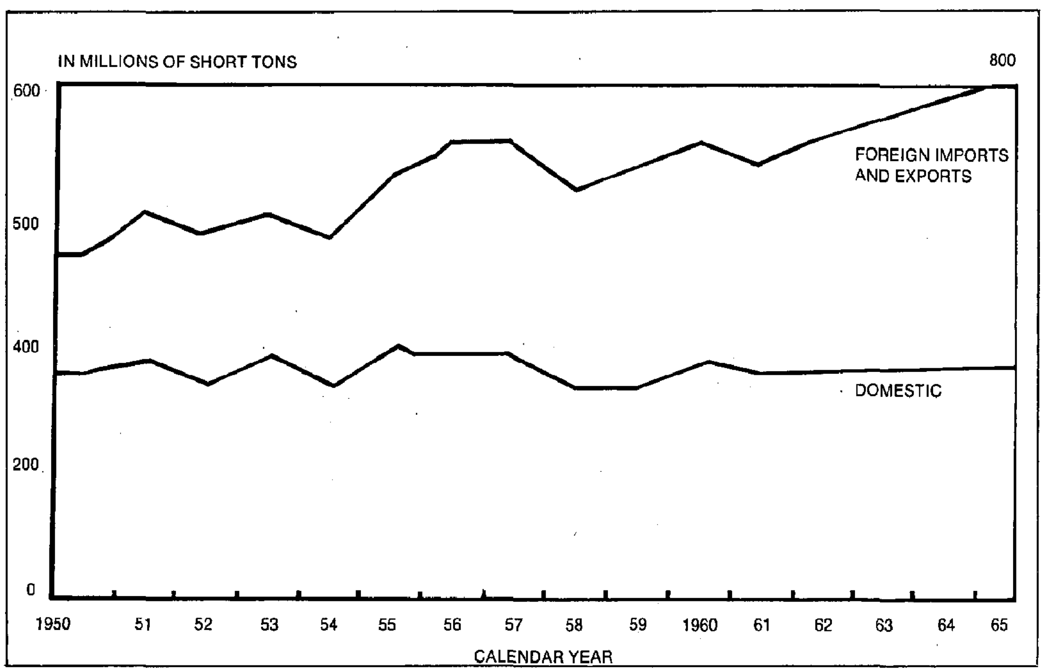

Figure 3. *Total oceanborne and Great Lakes foreign and domestic commerce. (Source: U.S. Army Corps of Engineers)*

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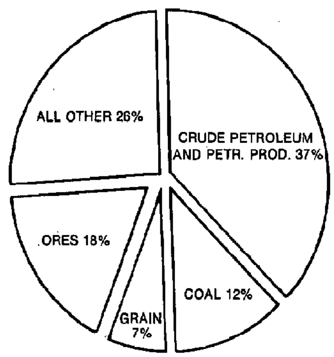
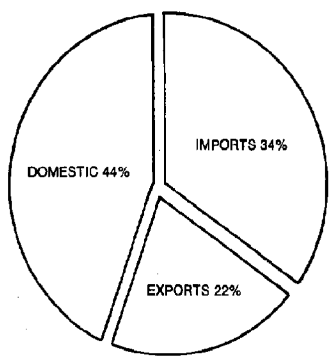
1945, the first supertanker,[12] 28,000 dwt, was constructed. In 1950, the first U.S. tanker in excess of 30,000 dwt was built; and by 1956, 11 U.S. tankers between 30,000 and 35,000 dwt were in service.

The average-size tanker in the world fleet increased from 12,800 dwt in 1949 to 27,100 dwt in 1965. During this same period, the typical U.S. flag tanker increased from about 15,000 to 25,000 dwt. The trend toward larger-volume tankers accelerated during the past decade. In 1966, over one-third of the world tanker fleet was composed of vessels 30,000 dwt or larger; further, these ships comprised about 64 per cent of the world fleet dwt capacity. While ships of 30,000 dwt have become common, they are dwarfed by the largest vessel now operating–a 312,000 dwt Japanese built tanker–and will look smaller still compared to the 760,000 dwt supercarriers under consideration.

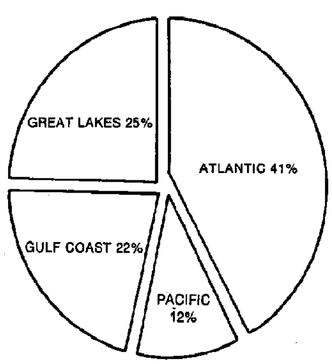
[12] The term "supertanker" changes meaning with each new generation of vessels.



1965 Commodity Distribution of Total U.S. Oceanborne and Great Lakes Commerce



1965 Distribution of Total U.S. Oceanborne and Great Lakes Commerce By Imports, Exports, and Domestic



1965 Regional Distribution of Total U.S. Oceanborne and Great Lakes Commerce (All figures represent tonnage distribution)

Figure 4. *Distributions of U.S. marine commerce. (Source: U.S. Army Corps of Engineers)*

B. Dry Bulk Carriers

Dry bulk vessels, which transport commodities ranging from iron ore to general cargo, have not grown at the same rate as their tanker counterparts.[13] Nevertheless, the number of vessels 30,000 dwt and larger now in service comprise about 16 per cent of the world's dry bulk carrier fleet compared to less than 2 per cent in 1953. Such vessels represent, at present, about 40 per cent of the world's fleet dry bulk tonnage capacity.

C. Vessel Size Projections

Table 4 is based on a recent study[14] which projected growth in the dead weight tonnage of freighters, dry bulk carriers, and tankers. The table summarizes anticipated vessel sizes and shows expected physical characteristics.

V. TRANSPORT COST IMPLICATIONS

A. Tankers

Although the shape of a 200,000-ton supertanker and a 17,000-ton T-2 tanker differs little, there is a major difference in the cost of shipping. The capital and operating cost per ton of vessel dead weight reduces substantially as vessel size

[13] In some instances, petroleum tankers are used to haul other goods, such as grain. Where this is done, the tankers must be thoroughly cleansed of all petroleum residue to avoid contamination of the grain. Cleansing is an expensive operation and is practiced only where several consecutive grain cargoes can be secured.

[14] U.S. Maritime Administration, *Merchant Ships of 100,000 Tons Deadweight and Over,* April 1967.

Table 3

UNITED STATES WATERBORNE FOREIGN TRADE 1956-1965
WITH PROJECTIONS TO 2000
(millions of long tons)

	1956	1960	1965	1970	1975	1980	1985	1990	1995	2000
TOTAL TRADE	260.0	277.9	348.5	391	471	564	685	837	1024	1252
Liner	46.4	50.7	50.2	55	59	64	69	75	80	87
Irregular	116.0	109.0	169.9	184	237	300	381	492	629	800
Tanker	97.7	118.2	128.4	152	175	200	235	270	315	365
EXPORTS	111.1	96.1	134.7	137	164	193	231	282	342	417
Liner	28.6	32.2	29.1	33	36	38	41	45	48	52
Irregular	68.4	49.0	86.8	89	113	140	175	222	279	350
Tanker	14.1	14.9	18.8	15	15	15	15	15	15	15
IMPORTS	148.9	181.8	213.7	254	307	371	454	555	682	835
Liner	17.8	18.5	21.1	22	23	26	28	30	32	35
Irregular	47.6	60.0	83.1	95	124	160	206	270	350	450
Tanker	83.6	103.3	109.5	137	160	185	220	255	300	350

Source: 1956-1965, Department of Commerce, Bureau of Census; 1970-2000, Projections by the Office of Economics, Assistant Secretary for Policy Development, Department of Transportation.

Table 4

PROJECTED VESSEL CHARACTERISTICS
1970 to 2000

	1970	1980	1990	2000
Freighters				
Maximum DWT in world fleet	25,500	33,500	43,500	50,000
Length (feet) .	850	930	1,010	1,050
Beam (feet). .	108	117	127	132
Depth (feet) .	74	80	85	88
Draft (feet) .	36	39	40	40
Average DWT in world fleet .	8,168	8,583	9,043	9,350
Bulk Carriers				
Maximum DWT in world fleet	105,000	185,000	317,000	400,000[1]
Length (feet) .	870	1,040	1,230	1,325
Beam (feet) .	125	152	183	198
Depth (feet) .	71	84	99	106
Draft (feet) .	48	57	66	71
Average DWT in world fleet .	14,750	18,750	23,575	27,350
Tankers				
Maximum DWT in world fleet	300,000	760,000	1,000,000[1]	1,000,000[1]
Length (feet) .	1,135	1,460	1,570	1,570
Beam (feet) .	186	252	276	276
Depth (feet) .	94	129	142	142
Draft (feet) .	72	98	104	104
Average DWT in world fleet .	39,825	76,225		94,325

[1] Uppermost practical limit, based upon projected technology and experience.

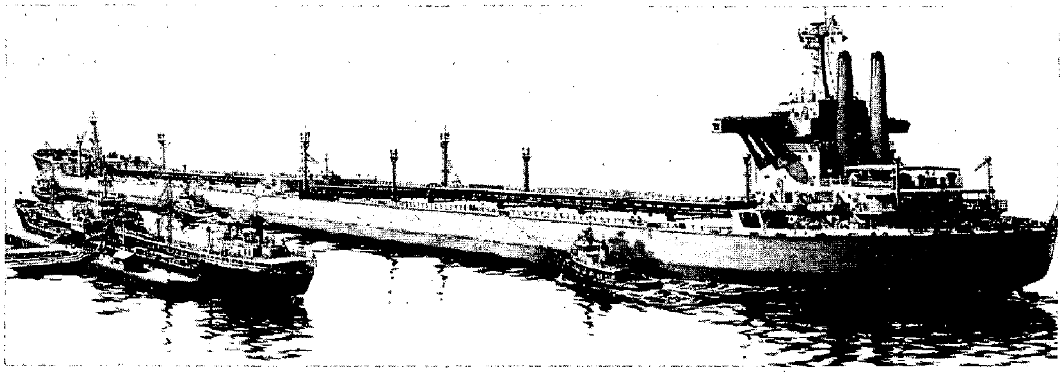


Figure 5. *The modern supertanker dwarfs the conventional tanker of World War II. (Courtesy of the Reader's Digest Association © 1968)*

increases, resulting in marked savings in delivered unit costs.

B. Containers

Paralleling the growing size of vessels, in terms of transport cost reductions, is on-going, radical change in handling non-bulk cargoes–the move to containerization. The use of standard sized van containers (8 feet wide, 8 feet high, and 10, 20, 30, or 40 feet long), which are enclosed, permanent, reusable, and weather tight, promises to virtually revolutionize ocean transportation operations.

The containers can be loaded with goods at a factory far inland and then transferred to truck, train or ship without being unsealed until they reach the customer. The sealed boxes travel routinely from inland producers on one side of the Atlantic, for example, to inland consumers on the other.

The shipping industry is investing substantial sums in constructing new ships specially designed to handle containers and refitting older ships for the same purpose. Major benefits of the containerization process have been identified as: reduced handling and pilferage; reduced damage to cargoes; faster delivery, with ships in port only hours instead of days; and significantly reduced insurance rates. Presently, about 4 per cent of general cargo tonnage is moving in containers. It has been estimated that at least 70 per cent of the tonnage could be containerized.[15]

VI. IMPLICATIONS FOR HARBORS AND TERMINALS

The trends in ship size and cargo handling technology impose new requirements; one set relates to required depths for harbors and channels, another to requisite on-shore supporting or service facilities.

A. Harbor and Channel Dimensions

During the 1940's, the T-2 tanker (16,460 dwt) was used as a yardstick in determining that a depth of 35 feet was required at major U.S. ports. But tankers of 35,000 dwt required 40 foot depths and necessitated further enlargement of harbors and channels. The largest tanker in service today needs at least 70 feet. Figure 6 shows dwt-draft relationships.

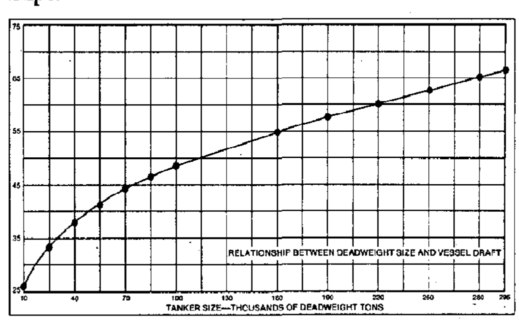


Figure 6. *Relationship between tanker tonnage and draft. (Source: U.S. Maritime Administration)*

At present, only 10 per cent of the world's major ports have controlled channel depths in excess of 47 feet;[16] only three U.S. harbors

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[15] R. P. Holubowicz, Transmodalism, *United States Naval Institute Proceedings,* February 1968.

[16] U.S. Maritime Administration, *Merchant Ships of 100,000 Tons Deadweight and Over,* April 1967.

qualify in this regard. This depth is barely adequate to permit transit of 100,000 dwt vessels.

Harbor and channel depths are not the only obstacles to the movement of supercarriers. Relatively shallow bodies of ocean water, such as the North Sea or Malacca Straits, may not be readily navigable to giant ships of 200,000 dwt or greater, except through specially surveyed and marked channels. The Suez Canal, with its 38 foot depth, is too shallow for such vessels.

B. Landside-Terminal Requirements

The tremendous volume of commodity deliveries associated with supercarriers likewise requires an expansion in supporting facilities, such as oil tank farms or grain storage areas. The inland distribution or "feeder" transportation network also may require modification to insure properly timed receipt or prompt dispatch of the huge commodity loads.

Even dry bulk vessels, with lesser dwt than the petroleum carriers, may necessitate significant changes in landside requirements and operations, especially to handle container units. The benefits of containerized shipping cannot be fully realized without the rebuilding of port-terminal-service areas requiring major capital investment. To cite one example, the Port of New York Authority already has invested $70 million to modernize its container terminal at Elizabeth, New Jersey.[17] An additional $115 million investment is contemplated by 1975 to fully develop a 919-acre, 25 vessel berth container facility.

The following is a listing and brief discussion of those factors most likely to influence major investment choices.

C. Dislocations and Major Relocations

Perhaps the most significant obstacle to major nationwide enlargement of harbor and channel facilities is the cost involved with relocations or dislocations. At the majority of U.S. harbors, extensive developments have grown at the water's edge. In many instances, this growth has progressed to the point where harbor or channel deepening, which must be accompanied by related widening of the navigation facility, would require removal and relocation of industrial, commercial, and residential structures.

For example, at Oakland, California, substantial deepening of the harbor would result in very high costs for modification of Army and Navy waterfront facilities, as well as the densely developed city waterfront area. The present Chelsea River Channel in Boston Harbor is dredged nearly berth-to-berth in several locations, and dislocations would become a serious problem if the channel were greatly deepened.

Other formidable obstacles can be illustrated. At New Orleans, oil wells located on top of and adjacent to the banks of the Calcasieu River and Pass Channel would have to be relocated if the navigation facility were much enlarged. Relocation of major land transportation facilities–most notably highway tunnels–could represent insuperable barriers at many ports. Instances of highway facilities passing beneath principal navigation channels include the port areas of Oakland, Baltimore, Mobile, Norfolk, New York, and Houston. While the restrictive impact of such obstacles will vary, it would take huge shipping-cost savings to justify any such massive relocations.

D. Changing Construction Conditions

A very large proportion of major U.S. harbor facilities have been man-made through removal of silt deposits. However, in a growing number of cases, further harbor deepening would entail more than removal of soft (overburden) materials. At present or authorized depths, the bottom of the overburden is being approached in many harbors and channels and further deepening would have to be through rock. When rock is encountered, construction costs increase enormously.

Another significant, changing condition is the problem posed by the contour of the Continental Shelf, particularly along the Gulf Coast. Here, the shelf gets progressively wider, reaches farther out to sea, moving eastward from the Mexican Border. Hence, the further east the port, the longer its entrance channel must be extended into the Gulf. For example, at Port Isabel near the Mexican border, the natural 50 foot depth is only 2 miles offshore; at Galveston it is 11 miles; and at Sabine Pass in East Texas it is 28 miles offshore. As a result, if the offshore 36 foot channel at Sabine

[17] Annual Report of the Port of New York Authority, 1967.

Figure 7. *Containership terminal at New York Harbor. (Port of New York Authority photo)*

Pass were to be deepened by only 4 feet, the approach channel would have to be extended for a distance of more than 15 miles.

E. Spoil Disposal

Problems of spoil disposal were introduced in Chapter 3. Disposition of material excavated from harbors and channels, both in original construction and maintenance, presents an increasingly serious impediment to further widening and deepening. Port area residential and industrial development already has created an acute—and rapidly growing—shortage of suitable shore disposal areas within the range of economic feasibility and aesthetic acceptance. The aesthetic criterion is becoming more and more a matter of public concern.

Within 8 to 10 years, existing spoil disposal areas at many major ports will have been filled. Channel maintenance or further development thereafter will depend on finding new acceptable disposal areas—a formidable challenge. Construction of new disposal areas through the building of retention dikes may offer relief. But dike construction is itself expensive and, in some cases, foundation conditions may make their construction infeasible or costs prohibitive.

The alternative to controlled land area spoiling is disposal in deep water. Yet, this option also might encounter difficulties. The cost of moving a million cubic yards of spoil just one mile is approximately $50,000—and in maintaining the present channels of a port such as Philadelphia, disposal work involves over eight million cubic yards a year.

Beyond the increase in financial costs, spoiling in deep water also may entail an ecological price. Deep water disposal increases water turbidity and care must be taken to avoid damaging shellfish or other wildlife. Finally, disposal of material taken from polluted harbors or channels entails a presently undefined but potentially significant problem, both aesthetically and ecologically.

F. Additional Factors in Port Improvements

Current and future investigations of harbor and channel improvements must take cognizance of impacts on ecological processes and wildlife resources. These considerations add substantially to the complex job of evaluating navigation improvements. Such impacts could add greatly to the cost of improvements, either in financial outlays to mitigate them or in the loss of wildlife resources.

In some cases, loss of wildlife resources may prove greater than the benefits of navigation improvements. For example, the James River, which flows into the Atlantic Ocean in southern Virginia, serves as the navigation outlet for the City of Richmond. However, conditions in the James River are ideal for production of seed oysters, and one of the Nation's foremost oyster beds is located in the James River estuary. Enlarging the channel, as has been proposed, could so alter bottom conditions and salt and fresh water relationships that the oyster resource might be seriously damaged, perhaps eliminated.

Another example of the influence of resource-environmental considerations relates to a reach of the St. John's River in Florida. Proposals have been made to canalize the section of the river between Lake Monroe and Lake Harney. However, this section is a principal spawning area for a significant anadromous fishery, the American shad. The shad run in the St. John's river has been increasing generally over the past decade and has come to represent an important commercial and recreation fishing resource.

Detailed investigations indicate that with a navigation project including locks, in operation, the water velocity in the river channel would be insufficient for shad spawning and hatching. Siltation conditions also would be modified, adversely affecting the fishery. Because of the potential damage to the shad resource, studies of navigation improvement have been suspended indefinitely.

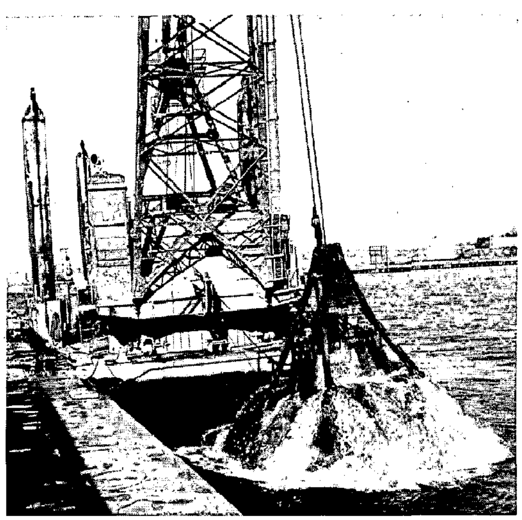

Figure 8. *Channel dredging at Providence, Rhode Island. Deeper channels may require removal of bedrock at great expense. (U.S. Army Corps of Engineers photo)*

Under certain circumstances, further extensive deepening of harbors and channels entails danger to another major resource—fresh water supplies. These underground supply sources, called aquifers, may extend under harbors or channels. It is possible that harbor or channel deepening operations could damage the impervious layer of protective rock, permitting salt water to seep into the aquifers and thereby degrade or pollute municipal water supplies.

A specific instance of this problem has been encountered in the study[18] of further navigation improvements on the Delaware River, which services the port of Philadelphia. Preliminary investigations indicate that deepening of the channel from its present 40 feet to a depth of 50 feet would necessitate blasting and removal of rock—impervious rock which now protects a major aquifer. A deepening project could, therefore, cause damage to the aquifer. The exact dimensions of the problem are exceedingly difficult to determine and evaluate, but the potential adverse effects cannot be ignored in project evaluation.

Channel deepening in estuary areas also can risk intrusion of tidal, salt water above those points where fresh water is drawn from channels for municipal or irrigation supplies. Again, referring to the Philadelphia study, deepening of the existing channel could lead to intrusion of salt water upon a major intake supplying fresh water to Philadelphia. Control barriers, including navigation locks, can be constructed to help control salt water intrusion. Yet such facilities add to project expense and could significantly complicate shipping operations.

Appendix C summarizes problems described in the preceding sections which would be experienced in deepening major harbors. Shown in the table are the present authorized depths for 102 U.S. harbors and depths at which problems due to dislocations, rock, Continental Shelf, water resources or ecology might occur. The data comes from various U.S. Army surveys and in many instances is very preliminary in nature.

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[18] U.S. Corps of Engineers, Preliminary Study of Navigation Improvements on the Delaware River, 1968.

VII. ECONOMIC ISSUES AND IMPACTS

Harbor and channel facilities are only one element in a constantly changing and improving transportation network. The emerging trends in commodity movements and vessel technology indicate important changes ahead for the whole transportation system. Vessels of 50,000 dwt are forecast to handle container-ship cargo and dry bulk vessels of 100,000 dwt are foreseen. Petroleum movements are forecast in vessels of up to 400,000 dwt size. If existing land distribution and terminal facilities are not capable of servicing these vessels, the transportation savings will not materialize to the fullest extent.

Information in the preceding sections indicates that development or redevelopment of harbor and port facilities will be an expensive undertaking for both public and private investors. In the absence of careful planning and implementation there is serious risk–to Federal as well as non-Federal resources–of large and uneconomical investments.

It also follows that with modernized harbor, channel, and terminal facilities capable of servicing larger geographic areas, that the number of receiving or shipping points for ultra-large bulk volumes can and should be restricted.

Careful planning also will be required to safeguard investments in container-service facilities, even though harbor-channel problems will be less severe than for supertankers. A recent report by the Maritime Administration stated clearly that mere modernization of any port will not insure the economic feasibility of improvements:

More than ever before, other factors will determine the new traffic distribution patterns. Factors such as inland transportation facilities and highway systems, which are both beyond the immediate control of port officials, will influence the routing of containerized freight. On the seaward size of the marine terminal and wharf facilities, the economics of interoceanic container movements dictate that the new full containerships will call at an ever-decreasing number of ports. The very nature of containerization and intermodal transportation make it possible to handle cargo as a thru service from an inland point of origin to an inland point of destination. This characteristic nullifies the principle that when modern terminal facilities are made available the traffic is sure to follow.[19]

As stated earlier, volumes of ocean trade are forecast to increase substantially. Consequently, the problem is one of determining which ports should be prepared to handle what type of traffic and in what volumes; what degree of port specialization will be required to insure an efficient and economically viable deep-water shipping network; what combination of investments, Federal and non-Federal, public and private, are needed to bring about an efficient system?

VIII. AN OUTLINE FOR PROGRESS

For a very sizeable number of U.S. cities, the waterfront and harbor area was originally the economic key to the development of the community and the related interior lands. When the cities were young, the waterfronts were living, dynamic areas which provided employment and recreation, market places and parks, warehouses and consumer outlets, and contact with nature at the water's edge. Today, many of these waterfronts are neither living nor dynamic, and nature has been crowded out or poisoned.

As pointed out, existing port areas are becoming obsolete because of rapid changes occurring and foreseen in transportation technology. Abandoned piers, warehouses and hulks clutter many of our waterfronts, contributing to harbor areas being a focus for decay and unsightliness.

These undesirable remnants, as well as the existing but technically inadequate terminal facilities, require replacement to permit more efficient servicing of larger, more productive ships.

The problem is highly complex. It transcends the ports themselves and includes the inland transportation networks, plus the recognition that the pattern of needs for seaports may be quite different in the future. It includes consideration of port and harbor operations on highly complicated ecological networks. It includes determination of pollution control in harbor areas and waterways. And it must consider the need for urban renewal and recognize growing requirements for recreation facilities in congested urban areas.

[19] Maritime Administration, "Information and Preliminary Criteria on Planning Container Terminals," December 1967.

New, more productive transportation technologies will permit more efficient use of waterfront space. A greater flow of trade and transportation can take place using less area, thus releasing valuable waterfront property for housing, open space, or recreation purposes. New technology can be applied to reduce the polluting of harbors and estuaries.

Any concentrated effort at port and urban waterfront development and redevelopment must involve several groups and will require a high degree of cooperation between local governments, regional planning groups, private interests, and the Federal agencies. An effective program can be visualized as having three major and closely related components:

–comprehensive surveys of regional port-transportation requirements

–development of action plans for port, harbor and waterfront area renovation

–integration of transportation and waterfront renewal planning with programs for conservation of estuarine resources

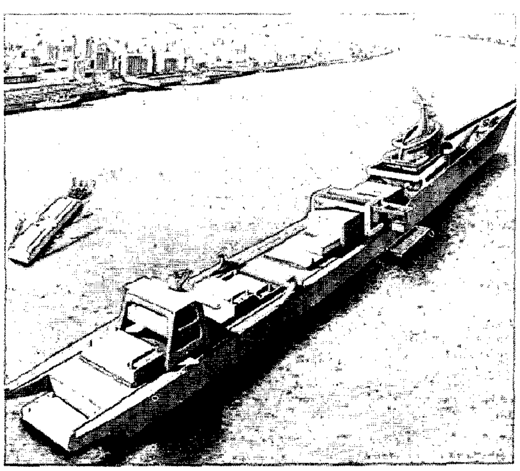

Figure 9. *An innovation in cargo handling which may have an impact on port requirements is Lighter-Aboard-Ship (LASH). Such a vessel is now under construction. (courtesy of Pacific Far East Lines, Inc.)*

Comprehensive surveys are needed to determine the optimum number and spacing of ports and the harbor and specialized terminal facilities required to accommodate changing vessel and cargo handling technology. The surveys cannot be confined to harbor or port development only. They must involve detailed analyses of trends in industrial growth and location, commodity movements and fleet composition; identification of implications, by regions, of projected economic activity, traffic movement and vessel size; analysis of port cargo handling and associated facilities, including all foreseeable technology required to accommodate prospective traffic; plus evaluation and recommendations for financial participation by states, local political entities, and commercial and industrial interests.

The studies should explore all technological alternatives of traditional harbor deepening, including installation of offshore transfer facilities or use of lightering vessels. Such alternatives may greatly reduce both the financial and ecological costs of accommodating supercarriers.

As short and long-range transportation requirements become identified for harbor and port areas, companion plans can be developed for rehabilitation of land areas adjacent to harbors, including consolidation and relocation of cargo handling and industrial facilities. The potential for offshore handling of petroleum commodities, coupled with the sharply rising use of containers, should provide many opportunities for land clearance and rehabilitation.

This is not to argue that waterfront operations must be sheltered from public view. To the contrary, where the waterfront use is for port facilities, the drama of docking and loading and unloading ships has a special fascination for both the local audience and tourists.

Such operations could be made readily accessible to the public from observation galleries which could include dock-side restaurants and educational exhibits. Whatever use is made of waterfronts is enhanced if access is easy and attractive. Where waterfronts are devoted to transportation, the street or rail arteries could avoid the waters' edge or be designed with tunnels, decks, depressed grades, or other techniques that can contribute to ease of public access to the area.

Based on the material developed in this chapter, a National port requirements study has been identified by the panel as a primary need. This recommended study is further described in Chapter 9.

I. THE NEEDS

The near-shore environment is modified by nature in a continuous and rapid way. Of all natural aquatic habitats the coastal zone is the most variable. It is this susceptibility to change, coupled with intensive, multiple, and often conflicting uses which has made its utilization so difficult to regulate. Good management of the inshore environment, however, is essential to assuring its maximum rational employment. Effective management, in turn, will largely depend on the ability to predict the results of man-made changes.

It is not that we are completely ignorant of the processes that occur in the coastal zone. If research grants by the National Science Foundation can be used as a yardstick, basic science in the coastal zone has more than doubled in the past 10 years.[1] However, although much has been learned in recent years, much remains to be learned. As the development of the coastal zone continues, and as the pressures increase, the problems become more difficult. Yesterday's level of understanding is inadequate for the kinds of decisions that need to be made today.

To gain the maximum benefit for each user of the near-shore areas, it will be necessary to provide a quantitative answer to the question: By how much can man alter a given estuary (or shoreline) without destroying one or more of its uses?[2] We need the answers to such questions as: What is the capacity of a given estuary to accept particular wastes, and can this capacity be increased? Can we develop artificial habitats and techniques for growing organisms either commercially or for other reasons? How will a wider or deeper channel affect circulation or sedimentation pattern?

Ecologists understand the importance of estuaries and marshlands as the nursery grounds of many varieties of sport and commercial fish, but the level of understanding is usually insufficient to answer such questions as how much of a given marsh area can be filled before a fishery is destroyed: 10 per cent? 50 per cent? 90 per cent? How can an estuary be managed to increase its productivity?

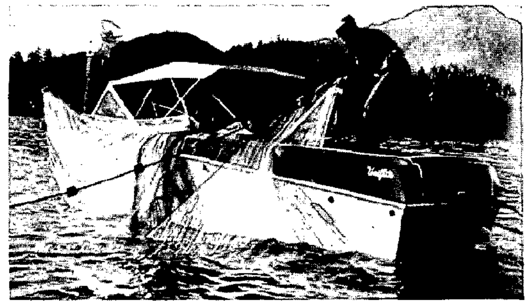

Figure 1. *Estuarine research into the life cycle of salmon. (U.S. Fish and Wildlife Service photo)*

It is well known that the shoreline is continually changing. Recent charts of Cape Cod show a different land distribution than those of the past. Some coasts erode while others build. When the shoreline was sparsely settled beach erosion was largely an academic problem, but as beach property increases in value the problems of surf zone dynamics and sediment transport are of increasing importance.

Not all the problems are in engineering and the natural sciences. Community planning and resource economics are among the additional skills that need to be applied to the coastal zone.

In the future the possibilities as well as the problems of coastal zone management will increase. Intentional modification of factors determining organic production is possible. Some coastal areas will be set aside for intensive aquaculture. In some circumstances, it is desirable to store and release river water; to divert large volumes; to alter channels, currents, and tides; or in other ways to introduce major alterations into the coastal zone. Proponents of such bold concepts must be able to evaluate the total results of the changes they seek. On the other hand, those who oppose such suggestions are often expressing fear of the unpredictable consequences, and their position might be altered if there were sufficient knowledge to permit accurate prediction and evaluation of all the results.

[1] Report of the National Science Foundation at panel hearings, Oct. 10, 1967. See also *Oceanography, The 10 Years Ahead,* Interagency Committee on Oceanography Pamphlet No. 10, June 1963, and Table 1, Chapter 7.

[2] This question and the ones immediately following were those most frequently raised at the panel hearings with the scientific community. Details of the hearings are given in an appendix to the Panel Reports.

In a sense the problem of the coastal zone will never be solved. All one can hope for is continually to increase our level of understanding of a very complex system. The research effort required is not a single crash program but a continuing effort on many different fronts.

To keep up with the problems of the coastal zone will require more trained people than are presently available, but education and training needs are not limited to scientists who will study these problems. The general public must be kept informed as well as their elected officials who will make decisions on the uses of the coastal zone. Here the academic community has a special responsibility. The experts must do more to make the public aware of the nature of the problems, probable consequences of a decision, and possible alternatives.

At present a lack of basic understanding is impeding our progress in several different areas, the most important of which are (1) waste treatment, (2) the effect of pollutants on living organisms, (3) estuarine dynamics, and (4) beach processes.

II. WASTE TREATMENT

Research in pollution cuts across many areas from design of new waste treatment techniques to development of less toxic pollutants, to attempts to restore eutrophic lakes, to an understanding of the effects of specific pollutants on specific species.

Technological advances are being made in purifying the effluent waters of industrial plants and municipal waste treatment plants. It is important that this work continue, and new secondary and tertiary treatment methods must be developed with an eye to cost-savings as well as to abatement.

Industrial and municipal waste effluents originate at a point source making treatment of the wastes relatively simple. A larger problem is that such pollutants as agricultural chemicals (herbicides, pesticides, and fertilizers) or lead from gasoline engine exhaust do not originate at point sources. Agricultural wastes present both a research and a regulatory problem. Research is needed in the development of rapidly degradable and more specific herbicides and pesticides and in the development of fertilizing techniques that will prevent excess runoff. Better agricultural chemicals and better techniques of application must be developed and their use enforced.

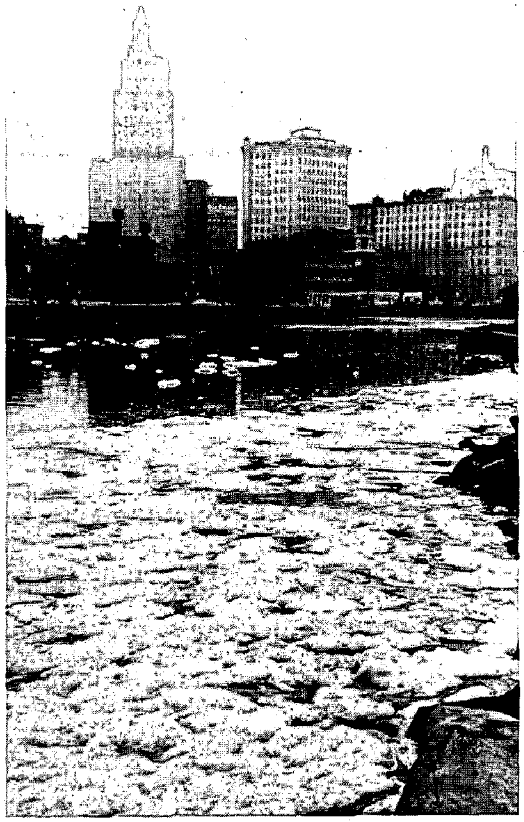

Figure 2. *Pollutants on Providence River, R.I. Research is needed into the identification and effects of pollutants. (Providence Bulletin photo)*

III. THE EFFECTS OF POLLUTION ON LIVING ORGANISMS

There are many areas in which ignorance contains our ability to deal effectively with pollution problems. Examples lie in the deficiencies of our knowledge of the behavior of important carriers of pollution, such as atmospheric gases, surface and ground waters, oceanic currents, and soil particles. Basic research on these topics is necessary in order to clarify our understanding of the movement of pollutants. Some pollutants are carried extensively in living things, moving from one plant or animal to another as food, moving from place to place with the plant or animal . . . Basic ecological research is necessary if we are to cope effectively with these serious problems.[3]

[3] "Restoring the Quality of Our Environment," Report of the President's Science Advisory Committee.

Critical gaps exist in our knowledge of the life history of even the most well known inshore species. In particular, details of the early life are lacking, and it is during this period that animals appear most susceptible to environmental insults. During this early period natural mortality is at its highest rate and techniques for environmental improvement could have their most positive effect. Answers to important questions of waste disposal —the timing, rate of disposal, and nature of materials which may be added into the sea—all depend on detailed life history studies. For example, temperate zone species are mostly seasonal spawners with egg and larvae production occurring primarily in late winter and early spring. Rational methods of pollution control to insure maximum benefits to each user of the coastal zone almost certainly must include a seasonal factor. However, our knowledge is inadequate to develop this factor and the most conservative stand must be taken to assure appropriate protection of our living resources.

The rapid development of large power plants using large quantities of water for cooling are adding another dimension to the pollution problem in the coastal zone. The outflow from these plants is of the order of 15-25° Fahrenheit above the incoming water. Again, larval forms of animals are usually least tolerant of such thermal shocks. However, in most cases we do not know the tolerance level.

Another unknown is the effect of specific pollutants on individual species at all stages of their life cycles. Understanding must be gained on these effects and on the long-term effects of chronic low level pollution on the total ecosystem. Of the eight classifications of water pollutants,[4] we do not understand the long-term effects of some nor the thresholds of allowable concentration for others.

Although any single source of pollution may be innocuous, the sum total of all sources may be very harmful and the combination of various pollutants may have a synergistic effect.

The long-term effects of low concentrations of pollutants on estuarine organisms will require studies in the pathology and histology of marine forms. These are little known at the present time. Invertebrate pathology in particular has been neglected. Nevertheless, pathological knowledge and medical research techniques can contribute to understanding the cause and effect relationships of pollution and fish diseases.

IV. ESTUARINE DYNAMICS

Advances of the past decade in instrumentation, signal processing theory, and computer data analysis have substantially increased our capability for studying estuarine circulation. Because the effects of turbulent motion in an estuary are usually more important than the mean values, it is necessary to carry out detailed, long-term programs to measure the turbulent fluxes of the various dissolved or suspended quantities. Because of their complexity, most estuarine studies have been highly empirical. With instrumentation now available, currents in an estuary could be examined well enough to allow a better understanding of the

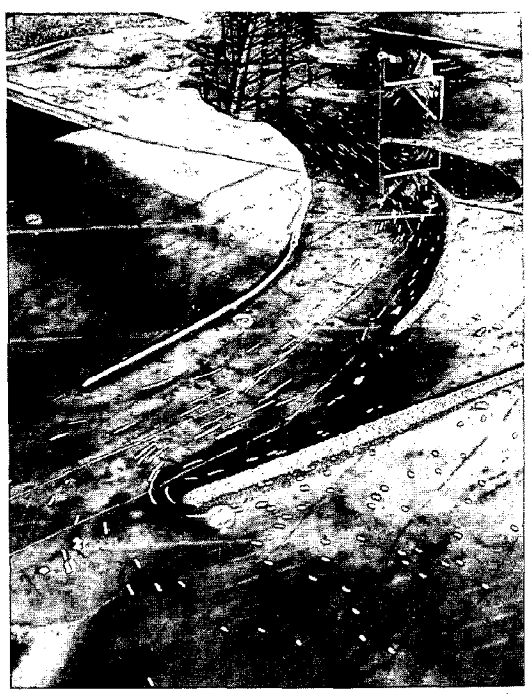

Figure 3. *Hydraulic model studies of Umpqua River estuary, Oregon, at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Such models contribute to the understanding of estuarine dynamics and the effects of engineering modifications. (U.S. Corps of Engineers photo)*

[4] The classifications of water pollutants are discussed in Chapter 4. They are BOD wastes, infectious agents, plant nutrients, organic chemicals, mineral chemicals, sediments, radioactivity, and thermal addition.

turbulent processes at work. Previously unanswerable questions, such as those concerning dilution of pollutants, migration of larvae, or transfer of sediment, could be approached rationally.

It is not unusual for the net circulation in an estuary to be hundreds of times stronger than the input from its fresh water source. Detailed, three-dimensional current surveys should be carried out in many estuaries to gather data on current patterns and variability throughout the tidal cycle, including seasonal variability. We need to ascertain what changes in a particular estuary will lead to greater useful circulation. We need to be able to avoid changes that might lead to an undesirable change in circulation, such as occurred in the oft-cited example of the diversion of the Santee River through Charleston Harbor.[5] In addition to field surveys, theoretical studies and careful analysis of the data must be given equal priority if results are to be of any lasting value.

V. THE MONITORING PROBLEM

In a system as complex as the coastal zone there is a need for continued monitoring and inventorying changing environmental conditions. The data are the necessary input to any study. They are also required to keep track of trends, to note changes, and to alert those responsible to any problems arising. Those who study the coastal zone require systematic data on such disparate parameters as beach slope, coliform bacteria, and land use patterns.

In some cases our understanding is not sufficient to design an efficient monitoring system. In many cases we are uncertain about the variables in an ecosystem—which are important and which, if any, can be safely ignored, which are primary and which are derivative.

Even when we understand the system, the measurement problem may not be easy. Changes take place in short distances and short time intervals in the estuarine environment and the range of values is great. For example, open ocean salinities vary in a narrow range of several parts per thousand. Estuarine salinities, however, varying from 0 to over 30 parts per thousand or more, change throughout the tidal cycle. In deep oceanic waters, salinity differences as small as 0.002 parts per thousand may be significant; in estuarine situations a salinity measurement having one-tenth this accuracy would be sufficient.

Detecting long-term changes of small magnitude is important. For example, when the annual natural variation of temperature is 30° Fahrenheit, an average annual increase of 0.5° Fahrenheit resulting from thermal wastes may be undetected; yet this small difference may be important to the estuarine biota.

VI. THE NEED FOR BASE LINE STUDIES

Because of the rapid development occurring in the coastal zone, many scientists have a strong feeling that certain areas must be set aside for detailed scientific study. In a letter to the Commission the National Academy of Sciences Committee on Oceanography[6] stated the requirement to:

Set aside unspoiled study areas for permanent scientific use. Such areas will be desperately

Figure 4. *Mote Marine Laboratory, Sarasota, Florida, is an excellent example of small coastal zone laboratories which are needed in all coastal waters to carry out a vital research effort.*

[5]The unanticipated effects of the diversion of the Santee River are described in the last section of Chapter 3.

[6]Letter from Dr. John C. Calhoun, Jr., Chairman, Committee on Oceanography, National Academy of Sciences, May 31, 1968. This largely reaffirms NASCO's views contained in its report *Oceanography 1966.*

needed 20 to 50 years from now. They can provide a "base-line" for detecting and documenting changes in the environment caused by large-scale introduction of materials and energy.

Such conservation of selected sites is of great scientific interest. It cannot be foreseen what basic questions man may wish to ask a century from now, or what measurements with yet-to-be-developed methods he may have to make to answer these questions. Eventually we will want to rehabilitate our polluted environments. To do so will be very difficult if an undisturbed eco-system of a comparable kind cannot be studied as a standard. Probably, there is today no estuary left on the U.S. east and Gulf coasts which is not measurably altered by man. In the future these changes are likely to accelerate because the rate of discharge of pollutant per capita increases with progressing industrialization of a country, apart from the continuing population growth. If there are no relatively unaffected areas set aside now, the only scientific standard or base-line in a 100 years will be the then-least-altered environment, which may be heavily polluted by today's standards.

An unspoiled area in the Pacific Northwest cannot serve as a fully representative site for east coast purposes because of the different plants and animals living in the two regions. Therefore, we should set aside preserves in the cool and warm regions of both the U.S. east and west coasts, and on the Gulf coast. Furthermore, in addition to preserves in estuaries, we should protect subtidal areas on open coasts.

VII. COASTAL ENGINEERING RESEARCH

Characteristics of a beach are determined by the forces to which the beach is exposed and the type of material available at the shore. Most beaches are composed of sand. The sand is supplied by the streams flowing into the ocean and by the erosion of the shores by waves and currents. Stone and mud beaches are relatively rare. Grasses usually grow in the mud; thus these shores are marshes. Mud and marsh beaches are found only where wave action is very mild.[7]

The characteristics usually used to describe a beach are: the average size of sand particles making up the beach, the range of sizes of those particles, the slope or steepness of the foreshore, and the general slope of the underwater portion of the beach from the foreshore toward deeper water (see Figure 5). Generally, the larger its sand particles, the steeper the beach.[8]

The short, steep waves of winter storms erode the beaches, taking the material from above sea level and carrying it into deeper water. Most of it is returned by the low, long swells of a typical summer season. Waves breaking at an angle to the beach set up currents which move parallel to the shore in shallow water. These long shore currents carry the beach sand—which has been stirred into suspension by the turbulence of the breaking waves—along the shore parallel to the beach.

Fresh water from rivers and upland streams flows to the sea, in some cases directly into the ocean and in other cases through bays or sounds. In this way sediments brought down by rivers and streams feed the ocean beaches. Beaches thus continually change. Sediment brought by rivers is winnowed and sorted by the along-shore movement of the beach sand the onshore-offshore sand movement caused by low swells and steep waves.

A particularly severe winter storm or hurricane may erode a beach to the extent that it will take several years to recover. Breakwaters may cause permanent changes in local beach conditions. On a National average our beaches are eroding. They are eroding largely because rivers no longer carry a replenishing sediment load to the oceans as in the past. Water diversion, which reduces river flow, and dams, which trap sediment—both reduce the availability of beach sand. An examination of records shows that eroding beaches are the general rule around our coasts and that accreting beaches are rare.

The relations between wind, waves, tides, sea level, and beach stability (or instability) are very complicated. The relations are fairly well understood on a qualitative basis but are insufficiently identified on a quantitative basis. The design of

[7] A detailed discussion of coastlines can be found in William C. Putnam *et al.*, *Natural Coastal Environments of the World,* ONR Contract Nonr-233(06), NR 388-013 (University of California, 1960).

[8] This description and much of the following material is taken from *Land Against the Sea,* U.S. Army Coastal Engineering Research Center Misc. Paper 4-64, May 1964, and Joseph M. Caldwell, "Coastal Processes and Beach Erosion," *Journal of the Society of Civil Engineers,* Vol. 53, No. 2, April 1966.

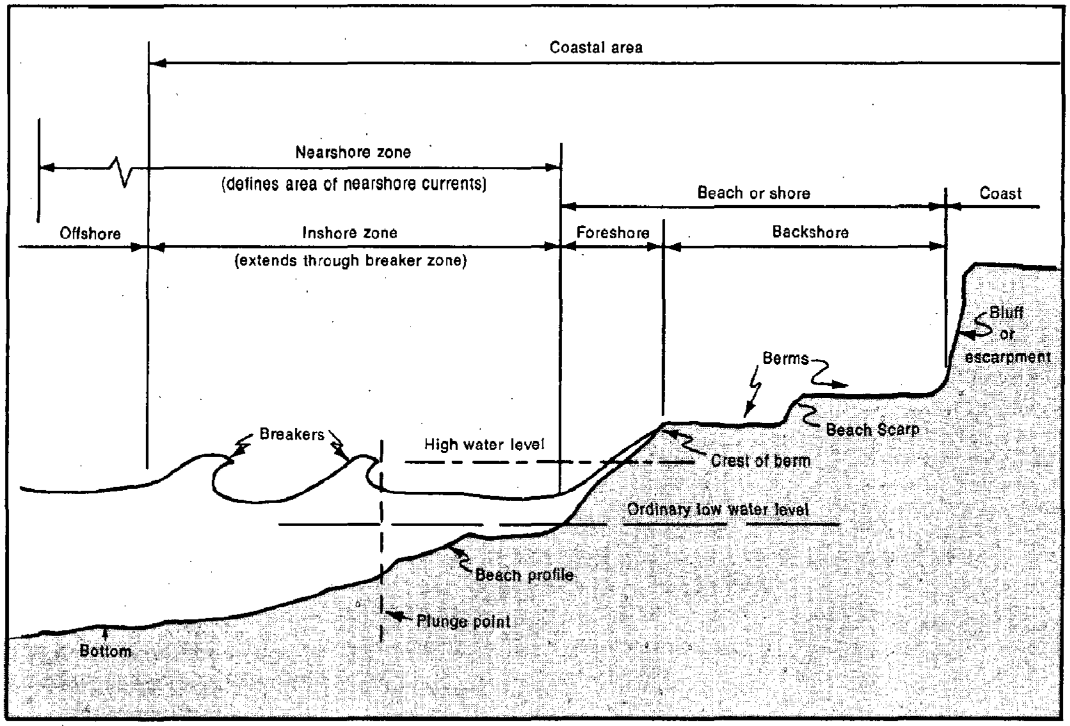

Figure 5. *Nomenclature of the surf zone.*

effective and economical engineering works to restore, stabilize, and protect our shores and beaches requires a quantitative understanding of shore processes. Research needed to establish this better quantitative understanding of physical processes in the shore zone can be classified into the following main categories:

–*Wave action in the coastal zone.* This concerns the generation of waves in coastal waters; transformation of waves onshore by bottom effects and coastal currents; development, installation, and operation of improved ocean wave recording equipment for statistical purposes; compilation and statistical analysis of ocean wave records; and the determination of design waves and their frequency of occurrence.

–*Sand movement in the inshore area.* This involves the quantitative relationships of wave characteristics and alongshore and onshore-offshore sand transport, effects of storm-wave action on inshore hydrography, interrelation of factors shaping a natural beach, sand transport and dune formation by wind action, and methods of stabilizing sand dunes.

–*Tides and surges.* This includes hurricane and tsunami surge generation, travel, and dissipation; effects of shore configuration on tide and surge ranges; and the mechanics of tidal flow in inlets and estuaries.

–*Coastal inlet studies.* This deals with the effects of wave action, tidal flow, freshwater flow, and littoral drift on inlet hydrography; migration of

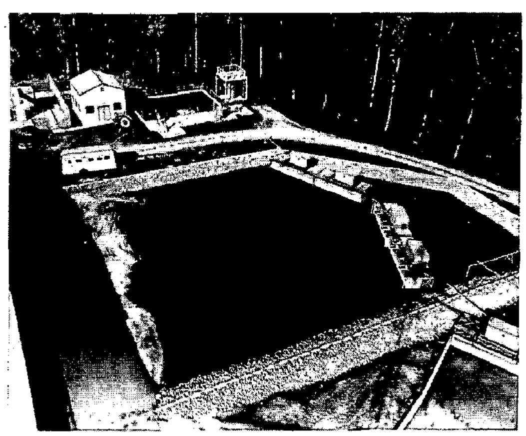

Figure 6. *Shore processes being studied at the test basin of the Corps of Engineers Coastal Engineering Research Center, Washington, D.C. (U.S. Army Corps of Engineers photo)*

inlets and bar channels; evaluation of factors affecting rate of shoaling of bar channels and salinity intrusion; study of tidal currents in inlets and their relation to tidal heights and inlet hydrography; and the development of an economical method of stabilizing and maintaining authorized navigation channels through coastal inlets.

–*Design of coastal structures.* Research is needed to develop improved criteria for the design of fixed coastal structures such as jetties and jetty channels, breakwaters for protecting harbor entrances, groins for protecting beaches, navigation channels and channel training works in tidal estuaries, and sand bypassing plants. The research includes determination of wave forces and runup on shore structures and the structural design required to withstand the forces and the soil mechanics and geology involved in their design.

In reviewing the activities and programs of Federal agencies, the panel has found that few Government organizations do not participate in some measure in coastal and estuarine activities. Participation may include direct operations such as those of the Corps of Engineers and Coast Guard, resource management and research such as carried on by the Fish and Wildlife Service and Public Health Service, and indirect participation through planning and funding such as by the Department of Housing and Urban Development.

State and local activities are described in some detail in a separate contract report[1] and only a brief summary is included here and in Appendix D. This review is limited mostly to Federal agencies and more specifically to those with a direct and significant role in the coastal zone. By "significant" is meant those agencies with a statutory mission in the coastal environment or activities unique to that regime.

The following Federal agencies have been selected, based on the foregoing, for attention. Hearings were held with these agencies[2] and their activities were examined in greater detail during the panel's field travels. In addition, presentations by these agencies to the National Council on Marine Resources and Engineering Development were made available to the panel. Levels of funding by Federal agencies for Fiscal Years 1968 and 1969 for activities relating to the coastal zone are shown in Table 1.

I. BUREAU OF COMMERCIAL FISHERIES (BCF)

The Bureau's background in coastal research goes back to the organization of the Old Fish Commission in 1871, stemming from recognition of the importance of estuarine habitat to most of this Nation's commercial fishery resources.

Approximately 65 per cent of the U.S. annual commercial fish and shellfish harvest, either by volume or value, consists of species that occupy estuarine areas at least during some phase of their life cycle.

The harvest comes to over three billion pounds annually, with a value of nearly $400 million to the fishermen.[3] Included are 7 of the 10 most valuable species or group of species in our commercial fisheries, such as shrimp, which supports our most valuable commercial fishery; menhaden, most important in volume; salmon, second most valuable; mollusks, third most valuable; plus at least 70 other commercially important species.

Estuarine and Great Lakes research is conducted in 14 of the Bureau's 20 biological laboratories. These are shown on Figure 1. Broadly speaking, activities may be grouped into:

–Research on commercially important species (life history, environmental requirements, causes of fluctuations, and development of management recommendations)

–Fundamental ecological studies of estuarine areas

–Applied ecology, including: (a) pollution studies (especially thermal, radiation, and pesticides), (b) review of proposed physical alterations in estuarine areas for potential damage to fishery resources, and (c) review of proposed water development projects and their anticipated effect upon fish and shellfish resources, with subsequent development of a report including recommendations for compensatory or protective features.

Although most of the Bureau's work is directed toward species of commercial importance, it is considered necessary to study the estuarine environment to develop more accurate fish forecasts, to gain a better understanding of why fluctuations occur, and to develop sound management recommendations.

[1] A Perspective of Regional and State Marine Environmental Activities: A Questionnaire Survey, Statistics and Observations, John I. Thompson Co., Contract Report to Institute of Public Administration for Commission on Marine Science, Engineering and Resources, Feb. 29, 1968, PB177765 of the Clearinghouse for Federal Scientific and Technical Information.

[2] Panel hearings with Federal agencies were held Oct. 9-12, 1967. See Appendix A for schedule and participants.

[3] Information furnished by Bureau of Commercial Fisheries in report to panel Feb. 13, 1968.

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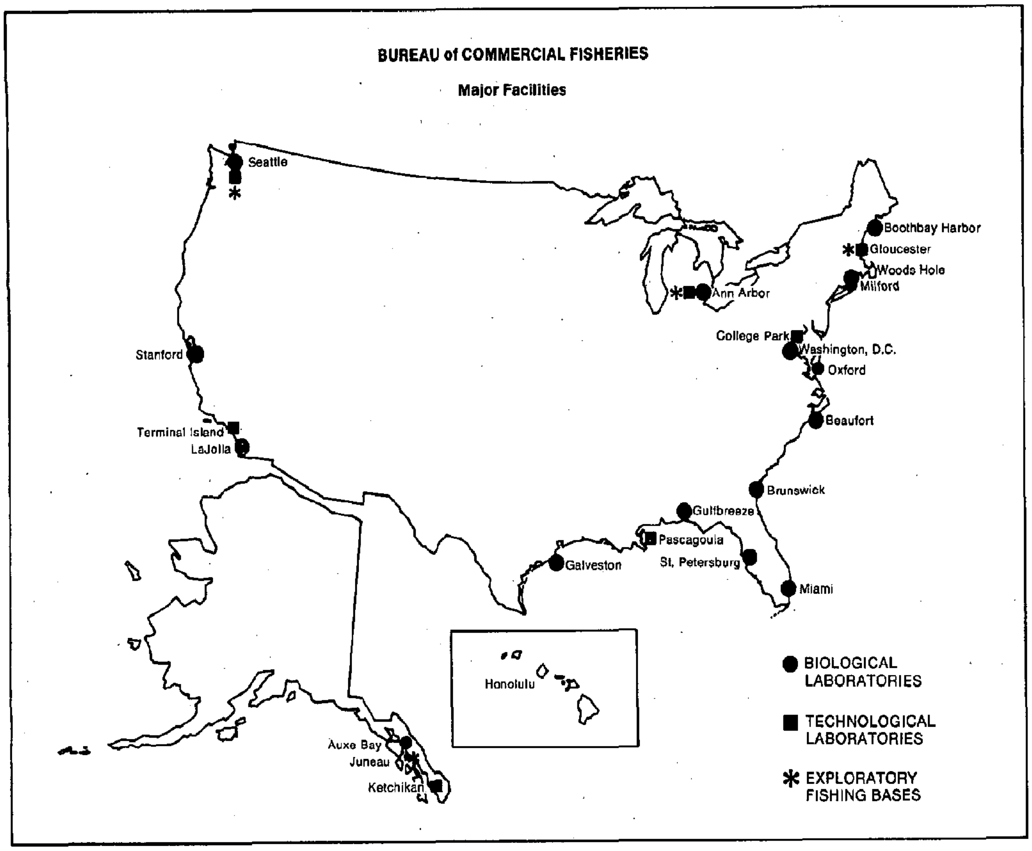

Figure 1. *Major facilities of the Bureau of Commercial Fisheries.*

The following table lists current funding for programs in the coastal zone:

	FY 68	*FY 69*
	(thousands of dollars)	
Research on estuaries and related problems	1,223	1,223
Coordination	25	25
Species research	1,202	1,216
Construction	0	0
Federal aid (P.L. 88-309)	686	686
Propagation research	4,570	4,777
Total	7,706	7,927

Under the Commercial Fisheries Research and Development Act (P.L. 88-309) the Secretary of the Interior can cooperate with the States on a cost-sharing basis to carry out estuarine research projects. Seventeen projects have been approved and funded in Florida, Louisiana, Maine, Maryland, Mississippi, New Jersey, North Carolina, Alabama, and Texas. Total cost is $929,563, with the Federal share 75 per cent.

BCF proposes added emphasis in three areas:

A. Mapping Resources of the U.S. Continental Shelf

This is envisioned as repetitive surveys to determine the seasonal availability and distribution of commercially important species. Though considerable work has been carried out in the past on resource mapping, it has been fragmentary and a mere fraction of that needed for a properly designed study of all Continental Shelves. The proposed program is three to four items that now being conducted and will be undertaken by Bureau vessels using conventional sampling gear.

The Bureau estimates the cost of this proposed program at about $4.0 million.

B. Aquaculture

The Bureau proposes a $5.3 million annual aquaculture program in the future. BCF claims more rapid development of aquaculture is neces-

Table 1
CURRENT FUNDING BY FEDERAL AGENCIES FOR ACTIVITIES RELATING TO THE COASTAL ZONE

Federal Agency	(millions of dollars) FY 1968	FY 1969	Source Note
Department of the Interior	(61.2)	(62.3)	
Bureau of Commercial Fisheries	7.7	7.9	1
Federal Water Pollution Control Administration	3.5	4.6	1
Geological Survey	4.7	4.9	1
National Park Service	8.2	7.8	1
Bureau of Sports Fisheries and Wildlife	7.8	9.8	1
Bureau of Land Management	–	–	2
Bureau of Mines	1.4	1.5	1
Office of Saline Water	0.4	0.3	1
Bureau of Outdoor Recreation	27.1	25.1	1
Office of Water Resources Research	0.4	0.4	1
Department of Commerce	(48.1)	(49.4)	
Environmental Science Services Administration	10.8	10.6	1
Maritime Administration	0.5	1.7	3
Economic Development Authority	36.8	37.1	5
Department of Transportation	(292.9)	(283.0)	
Coast Guard	287.8	272.5	1
St. Lawrence Seaway Corporation	5.1	10.5	4
Department of Health, Education and Welfare	4.4	4.8	1
Department of State	1.0	1.0	4
Department of Defense	(211.1)	(198.2)	
Corps of Engineers	196.0	183.0	1
Navy	15.1	15.2	3
Smithsonian Institution	0.2	0.2	1
National Science Foundation	6.4	6.4	3
Water Resources Council	0.3	–	5
Atomic Energy Commission	2.3	2.3	3
Federal Power Commission	–	–	2
Total	627.9	607.6	

Source:
1. National Council on Marine Resources and Engineering Development Panel Hearings, Sept. 23-25, 1968.
2. Figures not available or significant
3. Commission panel hearing, Oct. 9-12, 1967
4. U.S. Budget (Appendix) FY 1969
5. Separate communication to the panel.

sary because of increased foreign pressures on the declining potentials in waters fished by U.S. fishermen and because of continued loss of fishery habitat through increasing encroachments on the estuaries by urban and industrial developments.

Recommended emphasis includes three major areas:

–Freshwater pond culture–channel catfish

–Shellfish culture in coastal areas–oysters, clams, shrimp, northern lobster, and blue crab

–Artificial propagation of marine finfish–salmon, pompano, and other selected species.

Freshwater pond culture of channel catfish is not dependent on favorable habitat in the coastal zone and estuaries. Success in the shellfish culture and artificial propagation of marine finfish programs will depend in part on the degree to which favorable estuarine and coastal zone habitat is preserved.

C. Estuarine Research and Management

This relates directly to coastal dependent fishery resources and includes studies of productivity and nutrient cycling, determining the effects of changing environmental factors and heated effluents, classifying estuarine habitats, developing methods for rehabilitating damaged habitats, determining requirements for inflow of fresh water, and developing criteria for assessing effects of construction projects that would alter estuaries.

II. FEDERAL WATER POLLUTION CONTROL ADMINISTRATION (FWPCA)

This agency was created by the Water Quality Act of 1965[4] to administer the Federal Water Pollution Control Act,[5] formerly administered by the Public Health Service. FWPCA was transferred to the Department of the Interior by Reorganization Plan No. 2 of 1966, effective May 10, 1966.

Provisions of the Federal Water Pollution Control Act apply equally to the navigable and interstate waters of the estuaries, rivers, and lakes. Broadly, the Act's objectives call for the enhancement of quality and value of the Nation's water resources and for prevention, control and abatement of pollution. The agency is organized to accomplish these objectives and budgets are structured in terms of functions (such as research and development) and directed towards priority problems rather than in terms of estuaries, lakes, rivers, etc. Current funding for coastal programs is:

	FY 68	*FY 69*
	(millions of dollars)	
Comprehensive planning	1.0	1.4
Services and surveillance	1.4	1.6
Research and training	1.1	1.6
Total	3.5	4.6

Federal Water Pollution Control Administration efforts are focused on marine pollution problems through comprehensive planning, provision of technical services, enforcement actions, and research and development programs.

These resources support comprehensive studies covering the Great Lakes and most of the coastal areas; pollution abatement enforcement actions in 16 estuaries and Great Lakes; the National Estuarine Pollution Study authorized by the Clean Water Restoration Act of 1966;[6] a substantial number of relative small technical studies; and research and development projects, both intra- and extramural, designed to extend understanding of pollution problems and to develop more effective control measures. It can be expected that results of past efforts will become increasingly apparent and that pollution damage will be contained or reduced in many areas. The Comprehensive Planning Program and the National Estuarine Study also should help to point the way toward more effective use of the marine resource.

During the past 12 months Water Quality Standards have been prepared by States and submitted to the FWPCA. Once approved by the Secretary of Interior, Water Quality Standards also become Federal law and are enforceable as such.

Laboratory facilities operated or under construction by FWPCA are shown on Figure 2. Proposals for the future by the FWPCA include extending the Oil Pollution Act to include the contiguous zone and increased control measures for oil spills and wastes from watercraft.[7]

III. GEOLOGICAL SURVEY

The Geological Survey is responsible for investigations to provide information for exploration and extraction of minerals. It is charged with supporting the management of resources of the Outer Continental Shelf.

Principal objectives of the Geological Survey's marine geology program are:[8]

–In five years complete geologic field work required to prepare geologic analyses and maps of

[4]P.L. 89-234, Oct. 2, 1965, 79 Stat. 903.

[5]P.L. 84-660, May 9, 1956, 33 U.S.C. 466.

[6]P.L. 89-753, Nov. 3, 1966, 80 Stat. 1246. This study is described in Chapter 9.

[7]A major revision of the oil and water pollution acts was proposed in the 90th Congress (S. 3206 *et al.*) but failed to be enacted. See Chapters 4 and 9.

[8]Information furnished at hearings, Oct. 12, 1967.

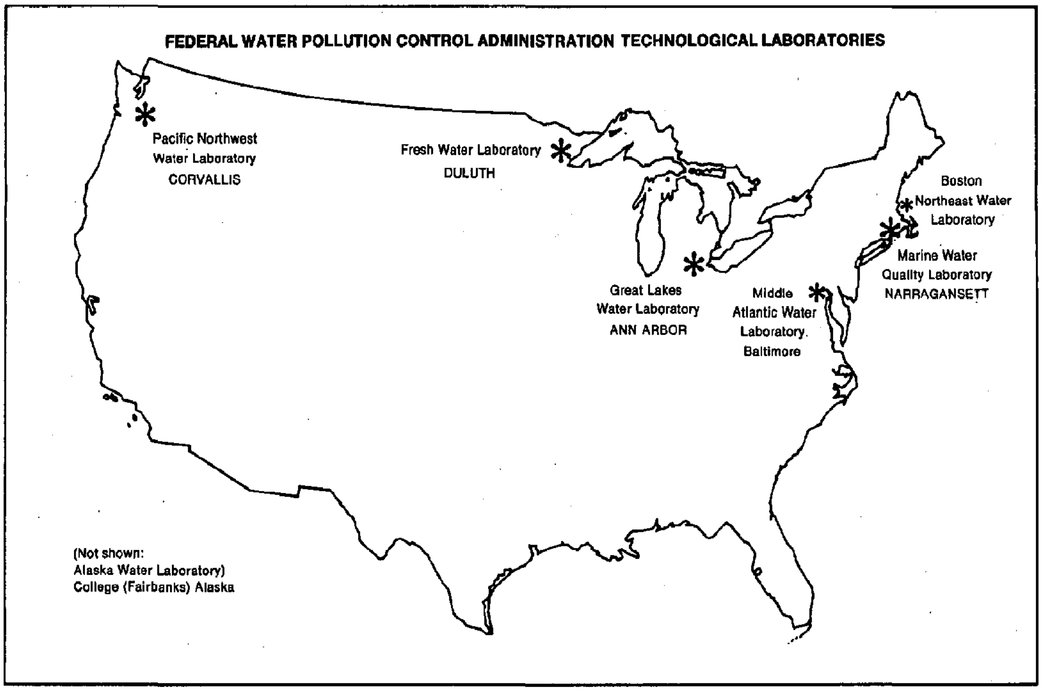

Figure 2.

12 critical areas (4-degree areas) at scale 1:250,000 (4 miles to one inch). Publication of reports and maps in seven years.

–In five years complete collection of basic information to prepare geologic analyses of all our continental margin, including reconnaissance maps, at a scale of 1:1,000,000. Publication of reports and maps in seven years.

–In 10 years complete field work for the geologic analysis of one half of the continental margins at a scale of 1:250,000.

–In 20 years complete geologic mapping of the entire continental margin at a scale of 1:250,000.

The Geological Survey's programs on the Great Lakes consist mainly of hydrologic studies and geologic mapping in the drainage basins peripheral to the Lakes and research into the basic hydrodynamics of the Lakes. About half the support for the data-collection program and the special investigations is furnished by the State or other local governments in the eight States surrounding the Great Lakes. Research on the Lakes includes projects to describe the circulation patterns collected by overflights.

The Geological Survey is involved in planning International Field Year on the Great Lakes and has prepared plans for work on the water budgets of the Lakes, and on the optical properties of lake water, lake currents, sediment transport and sediment characteristics, additional mapping of lake basin geology, surface chemistry as related to circulation patterns, the synoptic collection of data, and use of mass-transfer techniques to estimate evaporation.

Current funding by the Geological Survey for coastal and estuarine programs is given in the following table:

Types of Work	*FY 68*	*FY 69*
	(millions of dollars)	
Research and investigations	3.8	3.6
Basic data collection[9]	.9	.8
Coastal hydrology program	0	0
Resource evaluation and management	.9	1.2
Total	4.7	4.9

For the future the Geological Survey proposes an investigational and data-collection program in

[9]Coastal Zone streamflow and water-quality measurements are included in a nationwide "land" program and are not shown here.

estuaries and other coastal water bodies to be entitled "Physical Facts of the Estuarine Environment." The program in part involves the extension of on-going activities, but also includes a sizeable effort new in concept and scope in that it envisages a coordinated geologic, hydrologic, and topographic study. In general, it involves a substantial increase in basic data collection, investigations of related water bodies considered to be typical, and a sharp step-up in hydraulic research.

The Coastal Hydrology Program, proposed to begin in Fiscal Year 1970, includes enlargement of basic data collection especially in the coastal waters themselves, comprehensive scientific studies in selected estuaries, and step-up of hydraulic and hydraulic-related research. The funding of this program as proposed is probably substantially greater than can be approved for immediate implementation.

IV. NATIONAL PARK SERVICE

The National Park Service is responsible for administration of the National Park System, which includes 20 areas with significant marine resources. Eleven are National parks and monuments where resource protection is the major management objective, and nine are National seashores and lakeshores where recreation is the primary management consideration. Nine marine areas have been proposed for addition to the National Park System and five are under study.

The National seashores and lakeshores have only recently been added to the National Park System in order to reflect the need to protect outstanding stretches of shoreline, particularly near heavily populated urban areas. Cape Hatteras National Seashore was authorized in 1937, but not established until 1953. Cape Cod National Seashore was authorized in 1961, and authorization of Padre Island, Point Reyes, Fire Island, Assateague Island, and Cape Lookout National Seashores followed closely.

Last year, the Pictured Rocks in Michigan and Indiana Dunes National Lakeshores were authorized for establishment as National lakeshores.

Lands for the National parks and monuments were carved from the public domain or were donated to the Federal Government. Lands required for the National seashores and lakeshores, however, were largely privately owned and required special appropriations for purchase.

Appropriators for planning, development, conservation, and acquisition for the marine-related units under the management of the National Park Service are as follows:

	FY 68	*FY 69*
	(millions of dollars)	
Planning	.1	.1
Development	6.9	5.8
Conservation	1.2	1.9
Total	8.2	7.8
Acquisition (Bureau of Recreation)	11.1	13.2

Management programs at National seashores and lakeshores emphasize opportunities for such outdoor recreation as swimming, picnicking, hiking, bicycling, and camping. Natural and historical values are protected.

Marine life on coral reefs in the Buck Island National Monument and the Virgin Islands National Park can be viewed by underwater nature trails. Since many park visitors are unable to use the trails, the National Park Service currently is investigating other means of underwater observation.

V. BUREAU OF SPORT FISHERIES AND WILDLIFE

Bureau responsibility in fishery research related to estuaries is centered in its marine gamefish research, almost all related to coastal and estuarine zones. The central theme is to determine how and why the abundance, survival, distribution, migration, and well-being of game fish are affected by natural and man-made variations in the environment. In 1960, the first laboratory was established in what eventually will be a system of coastal research centers to carry out a coordinated nationwide program. Laboratories are at Sandy Hook, New Jersey; Tiburon, California; Narragansett, Rhode Island; and two Gulf of Mexico laboratories: Panama City, Florida and Port Aransas, Texas.

The National Wildlife Refuge system consists of Federal lands and waters dedicated to wildlife conservation. Activities include planning and executing a balanced management program for migratory waterfowl, upland wildlife, and other forms of wildlife in these areas; preservation of rare and endangered species; soil and water conservation; and compatible outdoor recreation. Of the 312 units in the refuge system, 78 are coastal installations and 42 of these contain significant estuarine areas. These are shown along with Bureau Laboratories on Figure 2.

Many of the refuges are superimposed on Corps of Engineers and Bureau of Reclamation projects and a few are administered jointly with Bureau of Land Management projects. Close coordination is required with these agencies to ensure that lands are managed to the best interest of wildlife consistent with the primary purpose of the project. Channel and dredging operations conducted by the Corps of Engineers may or may not be beneficial to wildlife refuge purposes. For this reason, considerable coordination is being effected by the Corps of Engineers and the Department of the Interior for both present and proposed research.

The appropriations for carrying out the Bureau's programs in the coastal zone are as follows:

	FY 68	*FY 69*
	(millions of dollars)	
Research and development	1.8	1.9
Investment	3.0	3.1
Operations	4.6	4.8
Total	7.8	9.8

In accordance with the Fish and Wildlife Coordination Act[10] the Bureau investigates, plans, and coordinates activities to preserve and develop fish and wildlife resources associated with a multitude of water development programs throughout the United States. The individual projects of these programs frequently involve

[10] Act of March 10, 1934, 48 Stat. 401, 16 U.S.C. 661.

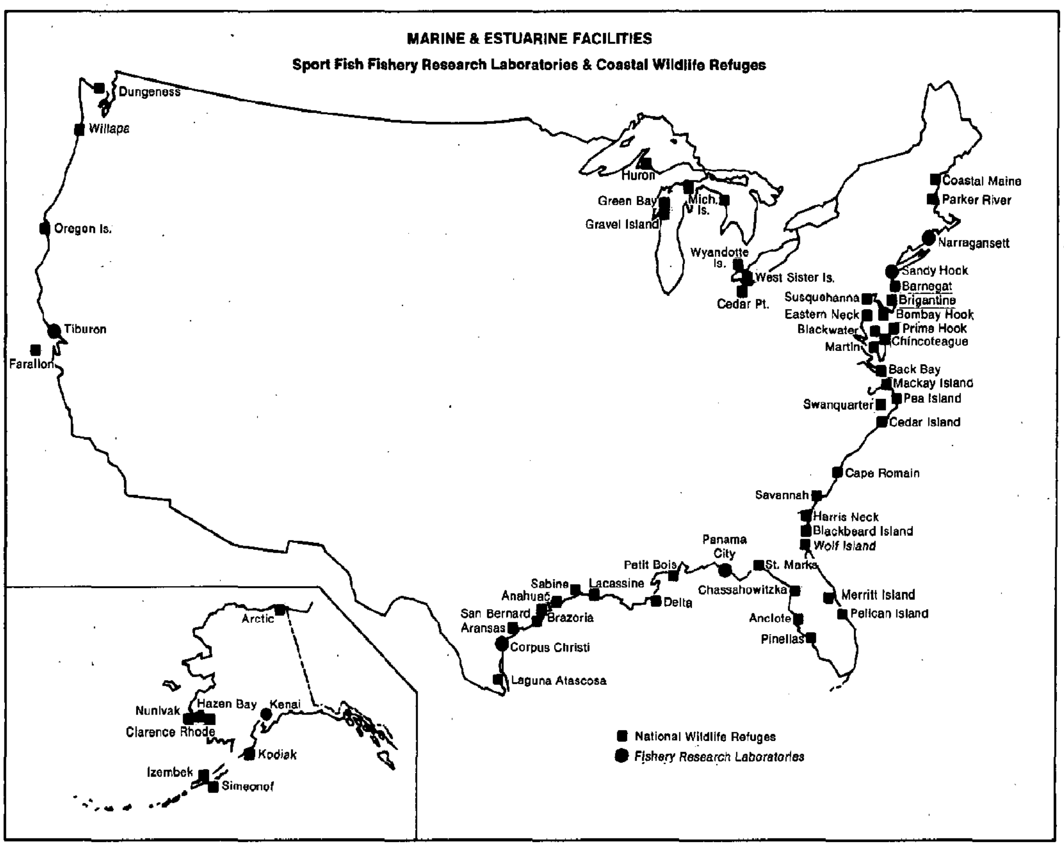

Figure 3.

estuaries and estuarine zones, directly and indirectly.

Most water-use programs and projects affecting estuarine habitat are planned and implemented by the Corps of Engineers, and to a lesser extent by the Bureau of Reclamation of the Department of the Interior and The Soil Conservation Service of the Department of Agriculture. Included also are non-Federal activities subject to Federal Power Commission license and non-Federal activities subject to Corps of Engineers permit.

VI. BUREAU OF LAND MANAGEMENT

The Bureau of Land Management administers the resources of the seabed and subsoil of the Outer Continental Shelf[11] by authority of the Outer Continental Shelf Lands Act.[12]

Exploration, leasing, and development of the submerged lands of the outer continental shelves were authorized Aug. 7, 1953. Since the first lease sale in 1954, over 1,300 mineral leases have been granted, with a bonus bid income of over $2.5 billion.[13] Royalty income from oil, gas, sulfur, and salt leases has totaled over $700 million from mineral production of $4 billion. Current royalty income exceeds $14 million per month.

VII. BUREAU OF MINES

The objective of the Bureau of Mines is to foster the growth of a U.S. industry-owned marine mining industry, and, in support of that goal, work with industry to:

–Develop data, tools, and techniques necessary to characterize marine mineral deposits and their environments

–Define mining systems requirements

–Advance the technology for industrial development of complete mining systems

–Contribute the technologic basis for resolution of environmental, including pollution, and legal aspects of marine mining

–Study the feasibility of recovery of additional minerals from seawater and of energy from the sea.

Emphasis is being placed initially on delineation, but will gradually shift to research and development applicable to mining systems. The sequence required to bring a marine mineral deposit into production is the same as on land, but mining technology involved is vastly different.

The Bureau operates a Marine Minerals Technology Center at Tiberon, California, and its research vessel *Virginia City* has conducted exploration in Norton Sound, Alaska, and off Oregon and California.

Current funding of the Bureau for coastal projects is:

FY 68	$1,400,000
FY 69	$1,500,000

VIII. OFFICE OF SALINE WATER (OSW)

Since 1952, the Department of the Interior through the Office of Saline Water, has conducted a research and development program to obtain low-cost means for saline water conversion.[14] Primary objective of the program is to provide development of practicable low-cost means for large-scale production of water of a quality suitable for municipal, industrial, agricultural, and other uses from saline water, and for studies and research related thereto. The term "saline water" includes seawater, brackish water, and other mineralized or chemically charged water.

[11] The definition and description of the Continental Shelf is found in the Convention on the Continental Shelf (1964), 15 U.S.T. 471, approved by 57 nations, including the United States, on April 26, 1958. The Convention entered into force June 10, 1964. The legal definition of the shelf is an area of major interest and the discussion of this definition and its important legal and international implications are presented in Chapter 1, Section III.

[12] P.L. 83-212, Aug. 7, 1953, 67 Stat. 462, 43 U.S.C. 1331-1343. This Act is discussed further in Chapters 8 and 9. For a more extended treatment, see Christopher, *Key to a New Frontier,* 6 Stanford Law Review 23, 28-31 (1953).

[13] Includes over $600 million realized in the lease sale of the Santa Barbara Channel lands, February 1968.

[14] The Office of Saline Water was established pursuant to Act of Congress July 3, 1952, 66 Stat. 328.

With desalting emerging as a new water supply source and large-scale plants being considered for coastal locations, the physical and financial problems of disposing of the brine effluent from the conversion process become increasingly more formidable. Included therefore as part of the research undertaken by OSW are studies directed towards assuring that the discharge of effluent from sea coast plants will not be harmful to the adjoining marine environment.

In this connection, OSW operates two major facilities in the coastal zone area: the Wrightsville Beach Test Facility in North Carolina and the San Diego Test Facility in California.

Current funding by OSW is:

	FY 68	*FY 69*
Brine disposal studies	$155,000	$200,000
Recovery of minerals from seawater	219,000	105,000
Total	$374,000	$305,000

IX. BUREAU OF OUTDOOR RECREATION (BOR)

The Bureau of Outdoor Recreation was established in April 1962 to serve as a focal point in the Federal Government for the many related activities. The BOR is charged to:

–Formulate and maintain a comprehensive nationwide outdoor recreation plan

–Coordinate the program of land acquisition by the National Park Service, Forest Service, and Bureau of Sport Fisheries and Wildlife.

The Bureau, under the Land and Water Conservation Fund Act of 1965,[15] administers a program of assistance to the States to plan, acquire, and develop outdoor recreation areas and facilities. The program is financed through revenues derived from the sale of entry and use permits at Federal recreation areas, sales of Federal surplus property, and the Federal motorboat fuel tax. Under the Act, each State is required to prepare and submit to the Bureau a Comprehensive Statewide Outdoor Recreation Plan to establish eligibility for program participation. All 50 States, plus the District of Columbia, Puerto Rico, and the three Territories, have now submitted plans which include provisions for meeting marine-related recreation needs and the preservation of significant coastal areas.

The estimated expenditures by the States and Federal agencies from fund sources for coastal projects are:

	FY 68	*FY 69*
	(millions of dollars)	
State		
Acquisition	8.0	4.4
Development	5.0	2.2
Federal[16]		
Acquisition	14.1	18.5
Total	27.1	25.1

The Bureau is conducting a survey of the recreation potential of islands off the coastline and on inland waterways and is developing a program to conserve these resources. This study is scheduled for completion by early 1969.

X. OFFICE OF WATER RESOURCES RESEARCH (OWRR)

The Office of Water Resources Research of the Department of the Interior administers the program of water resources research and training authorized by the Act of July 17, 1964.[17] The program promotes and supports research in water and water related resources and activities through water resources research institutes in each of the 50 States and Puerto Rico. The institutes are connected either with land grant colleges or an equivalent institutuion, and in general have a mission in water resources similar to that of the agricultural experiment stations in agriculture. Title II of the Act, which was modified and expanded by the Act of April 19, 1966,[18] provides for grants and contracts for water resources research at other institutions.

The OWRR supports research entirely by out-of-house allotments, grants, and contracts. Most of

[15] P.L. 88-578, Sept. 3, 1967, 78 Stat. 897, 16 U.S.C. 7601 *et seq.*

[16] This figure also includes the acquisition funds for programs of the National Park Service, Forest Service, and Bureau of Sport Fisheries and Wildlife.

[17] 78 Stat. 329, 42 U.S.C. 1961.

[18] 80 Stat. 129.

its activity is in non-coast-oriented water resource problems, but it does support a number of projects that are in the coastal zone. These currently are in three categories: general hydrology, water pollution, and resources planning.

Category	*No. of projects*	*Thousands of dollars*
FY 68		
Water cycle	8	180
Water quality management and protection	9	205
Water resources planning	4	48
Total	21	434
FY 69		
Water cycle	6	158
Water quality management and protection	10	107
Water resources planning	7	184
Total	23	449

XI. ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION (ESSA)

The Environmental Science Services Administration of the Department of Commerce was established on July 13, 1965, by Reorganization Plan No. 2 of 1965. The formation of ESSA brought together the functions of the Weather Bureau and the Coast and Geodetic Survey, the new agency's major elements. At the same time, the Institutes for Environmental Research, the Environmental Data Service, and the National Environmental Satellite Center were created. Also the Central Radio Propagation Laboratory was transferred to ESSA from the National Bureau of Standards and became the Institute for Telecommunication Sciences and Aeronomy, joining ESSA's Institutes for Atmospheric Sciences, Earth Sciences, and Oceanography.

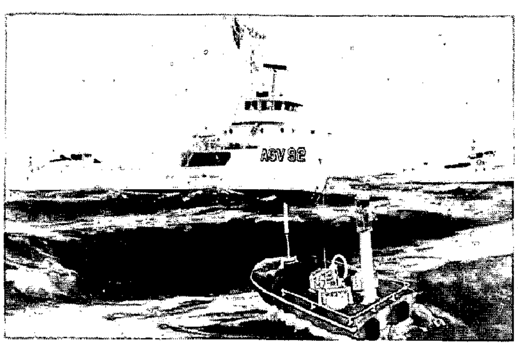

Figure 4. *Artist's rendition of Environmental Science Services Administration new data acquisition system (ODESSA) in operation. (Environmental Science Services Administration photo)*

ESSA's mission and functions include the following:

–Observe and collect comprehensive data about the state of the oceans and inland waters, of the upper and lower atmosphere, of the space environment, and of the earth

–Communicate, correlate, process, and analyze all such data

–Provide and disseminate such information with a prediction of future environmental states

–Prepare and disseminate warnings of all severe hazards of nature to all who may be affected

–Provide nautical, aeronautical, and telecommunications charts and related publications and services

–Operate and maintain a system for storage, retrieval, and dissemination of the acquired data

–Explore the feasibility of modification and control of environmental phenomena

–Coordinate Federal meteorological services and supporting research.

ESSA's hydrographic and ocean survey program is conducted jointly by the Coast and Geodetic Survey and its oceanographic laboratories. Its objectives are the charting of depths and topography of the coastal zone; delineation of major ocean currents; and completion of geophysical studies of the continental shelves and estuaries and other coastal features of the nation's shoreline.

ESSA publishes approximately 800 different nautical charts covering 2½ million square miles of the nation's navigable waters.

Standard nautical charts are supplemented with a series of U.S. Coast Pilots, providing information on navigation, regulations, landmarks, and other pertinent information.

ESSA's shoreline mapping programs employ Coast and Geodetic Survey aircraft and metric cameras for aerial photogrammetry and infrared photographs permitting accurate delineation of the shoreline and legal boundaries.

ESSA's tide program includes a network of tide gauges to calculate and publish the times and heights of high and low waters for 83 primary stations.

Observations from temporary tidal current stations predict average tidal currents and perform circulation studies of tidal estuaries. Predictions are made of the times of slack waters and the times, speeds, and directions of maximum tidal currents for 25 primary U.S. coastal and harbor stations. Similar predictions can be made for about 2,000 additional locations.

During 1968 flushing prediction service was implemented in several Maine estuaries to predict and control the dispersal of industrial wastes. Plans call for expansion of this program in both scope and size. In addition, other services related to environmental pollution and its abatement include air pollution potential advisories, now prepared for several urban areas on a routine basis; river flow forecasts by the Weather Bureau; and a number of special services, such as prediction of trajectories for radioactive fallout. Research in environmental pollution covers estuarine studies, atmospheric radioactivity, trajectories, pollution chemistry, and certain aspects of air turbulence.

The Coast and Geodetic Survey of ESSA operates the National Tsunami Warning Center for the Pacific Ocean area. This service was inaugurated after the destructive tsunami of April 1, 1946. The Center at Honolulu evaluates the tsunami potential of earthquakes reported in the area and issues alerts and warnings where indicated to the various countries bordering on the Pacific that participate in the service. Tsunami research is directed primarily toward improved prediction methods consisting of mathematical prediction models continually modified by tide gauge data inputs.

The Weather Bureau's Marine Weather Service supplies weather and sea state forecasts, warnings, and data for the conduct of coastal and marine operations.

Weather forecast and warning bulletins are issued at six-hour intervals for coastal waters up to 50 miles offshore. They are broadcast by the Coast Guard, marine radio-telegraph and radiotelephone shore stations, and more than 2,000 commercial radio and television stations. Dissemination also is provided by nine new ESSA VHF-FM continuous broadcast marine weather stations on the East, West, and Gulf Coasts. Visual displays at more than 550 stations also warn of approaching storms.

The National Hurricane Warning Service, operating through several Centers, is responsible for alerting the public to hurricanes and other tropical storms. The Centers furnish basic hurricane advisories and bulletins coordinated for prognosticated hurricane positions, tropical weather outlook, and post-storm reports. The Centers also conduct research and development to improve detecting and predicting hurricanes and the tropical weather processes leading to their formation.

ESSA's coastal radar system locates and tracks ocean storms, and is a critical part of the protective network for hurricane warnings. Special observations from the Cooperative Hurricane Networks along the Atlantic and Gulf Coasts as well as tide gauge networks play important roles in the National Hurricane Warning Service.

Major ESSA facilities in coastal programs are:

–Atlantic Oceanographic Laboratories
Physical Oceanographic Laboratory, Miami
Land and Sea Interaction Laboratory, Norfolk
Sea Air Interaction Laboratory, Miami
Marine Geology and Geophysics Laboratory, Miami

–Pacific Oceanographic Laboratories
Pacific Oceanographic Research Lab., Seattle
Joint Oceanographic Research Group, Seattle
Joint Tsunami Research Center, Honolulu

–National Hurricane Research Lab., Miami

–Environmental Data Services, Washington, D.C.

–National Environmental Satellite Center, Washington, D.C.

–Atlantic Marine Center, Coast and Geodetic Survey, Norfolk

–Pacific Marine Center, Coast and Geodetic Survey, Seattle.

Appropriations shown below have been extracted from other program categories to reflect the level of ESSA activities in the coastal zone.

	FY 68	*FY 69*
	(millions of dollars)	
Surveys and observations, processing analysis compilation, and printing	9.6	9.6
Research and development	0.5	0.5
Facilities, equipment, and construction	0.7	0.5
Total	10.8	10.6

Future plans envisioned by ESSA include:

–An accelerated and comprehensive program to determine the circulatory characteristics of near-shore waters necessary to the proper development of coastal zone resources. This program, estimated at about $4 million, will include detailed surveys of the circulation patterns of the various gulfs, bights, sounds, bays, estuaries, and inner shelf.

–Seaward boundary determination including a comprehensive low water line mapping program. This is estimated at about $5.5 million and would serve to resolve jurisdictional and other legal gaps resulting from an incomplete knowledge of our exact shoreline boundaries.

XII. MARITIME ADMINISTRATION (MARAD)

The Maritime Administration of the Department of Commerce has certain well defined legislative and promotional responsibilities for administration of Merchant Marine, Sales and Shipping Acts, 1936, 1946, 1920, 1916 and 1928, as amended, together with certain related Acts. The provisions of these Acts enable the agency to further develop and maintain an adequate and well-balanced American Merchant Marine, to promote U.S. commerce, and to aid in the National defense. It is consulted in matters concerning the enhancement in quality and value of the Nation's waterways, and for prevention and abating pollution attributable to ships. The agency's budgets are structured in terms of office functions such as Ship Construction, Research and Development, Maritime Promotion and Operations.

Financial aid is available to the marine industry in the form of construction differential subsidy for new ship construction; operating differential subsidy for operating ships, Title XI mortgage insurance, and in the provisions of ship exchange legislation.

MARAD has initiated provision for sewage treatment facilities in its new construction program and has sponsored research concerned with the prevention of oil pollution. As reported,[19] its current program consist of:

–Nineteen aerobic-type treatment units currently being installed in vessels under construction

–Provision for common soil line connections and space for sewage treatment plants on 22 vessels under recent construction and for all new construction

–A research contract to develop a marine oil-water separator system employing the principal of static coalescence

–A research contract to develop a rapid and automatic means of monitoring oil concentration in water

–A research contract for a compact, low-cost oil-water separation system, using standard proprietary equipment, to meet current international oil discharge requirements of 100 parts per million

–Requiring, where feasible, installation of clean water ballast tanks in its new ship construction program.

Maritime Administration funding which may be attributed to the coastal zone is chiefly the Ports and Systems Program. Funding is as follows:

FY 68	$ 475,000
FY 69	$1,700,000

Future plans of the Maritime Administration envision the following concepts:

–Development of a port "control tower" would (1) reduce the retardant effects of multiple, uncoordinated Federal agency activities, (2) facili-

[19] Information furnished at Panel hearings, Oct. 11, 1967.

tate entrance and clearance of ships, cargo, and passengers, and (3) implement recommendations of the existing international waterborne transportation facilitation conventions dealing with ports.

–Investigation and development of those types of bulk cargo transfer facilities would (1) reduce ship traffic in congested port areas and channels, thereby reducing safety hazards and pollution of ports and adjacent areas, (2) provide water depths adequate to accommodate the larger bulk carrying ships in existence and planned, and (3) reduce the susceptibility of U.S. tanker terminal facilities to enemy attack.

XIII. ECONOMIC DEVELOPMENT ADMINISTRATION (EDA)

EDA is responsible for administrating the Public Works and Economic Development Act of 1965 as amended. The Act provides for technical and financial assistance to economically distressed areas, designated by severe unemployment or underemployment as compared with the national economic posture. Included in this are some areas bordering on the coastal zone. This agency structures its budget in terms of functions (such as technical assistance, business loans, public works) rather than in terms of geographic areas.

EDA stimulates the economy of an area through projects for technical assistance and research, business loans, and public works.

Funding of such endeavors in the coastal zones is estimated below:

	FY 68	*FY 69*
	(millions of dollars)	
Technical assistance and research	3.1	3.0
Business loans	4.5	4.0
Public works	29.2	30.1
Total	36.8	37.1

EDA has contributed considerably to coastal zone development. About 200 projects representing $178 million have been approved. Of these 64 are technical studies. There have been 20 business loans granted. The remaining 116 projects are for such public works as docks, piers, marinas, cargo handling installations, warehousing, industrial parks, roads, water and sewer systems, etc.

XIV. COAST GUARD

The Coast Guard today is made up of the former Revenue Cutter Service, U.S. Lifesaving Service, U.S. Lighthouse Service, and the Bureau

Figure 5. *Coast Guard unit assisting at the scene of a ship collision. The Coast Guard engages in a wide variety of marine activities. (New Bedford Times photo by Ronald Rolo)*

of Marine Inspection.[20] Formerly under the Department of Treasury, it was placed under the Department of Transportation when that Department was established in 1967.[21] A military service and a branch of the U.S. Armed Forces at all times, the Coast Guard operates under the Navy in time of war or when the President directs.

The Coast Guard in the coastal zone provides search and rescue services, administers merchant marine safety laws, maintains a state of readiness for military operations in time of war or national emergency, provides a comprehensive system of aids to navigation for the Armed Forces and marine commerce, undertakes an effective port security program, and enforces or assists in enforcing Federal laws on the high seas or waters subject to U.S. jurisdiction. It also conducts oceanographic research[22] and provides ice-breaking services.

A. Search and Rescue

The search and rescue function is the largest Coast Guard program in terms of personnel, funds, requirements, and facilities operated. Its objective is to provide effective assistance to persons and property in immediate or potential distress in and over the high seas and waters subject to U.S. jurisdiction.

To carry out its objective the Coast Guard employs cutters of several sizes varying from the 82 foot patrol boats to the high endurance cutters, small boats of all types, long and medium range fixed wing aircraft, helicopters, a widely scattered network of shore stations, and an extensive rapid communications system. These facilities are integrated into the National Search and Rescue Plan and are used to fulfill the bulk of U.S. search and rescue obligations required by international treaties.

In 1967, the Coast Guard rendered assistance within the coastal and harbor zone[23] to 31,551 vessels, 543 aircraft, and 3,422 individuals and was involved in 2,473 other incidents; 2,296 lives were saved. Property assisted had a total evaluation of $1,361,422,900. In addition to responses by regular forces, the Coast Guard Auxiliary answered 6,877 calls for assistance within this zone.

B. Aids to Navigation

Navigable U.S. waters are marked to meet maritime commerce needs. They include interior and coastal waters, and approaches to rivers and harbors. Channels, obstructions, and shoals are marked for the deepest draft U.S. registered vessels expected to use a waterway.

Objectives are met by establishing and operating long- and short-range systems in the United States and its possessions to meet the needs of maritime commerce, and world-wide to meet Armed Forces needs. Private aids supplement the Federal system where maritime needs are insufficient to warrant Federal aids or when obstructions are placed in navigable waters by private concerns. Authorization and inspection of private aids is required by Federal regulations.

The short-range system is a passive, visual, electronic, and audio network of some 44,000 buoy, lightships, light stations and radio beacon stations located in the United States and possessions. The aids to navigation system as defined by Federal regulations specifies a lateral system of buoyage with prescribed characteristics having specified meanings. The short-range system is designed with the assumption that mariners understand the lateral system and have access to up-to-date charts of areas of operation.

The present long-range system LORAN (Long Range Aids to Navigation) is an electronic system incorporating 45 LORAN-A, 22 LORAN-C transmitting stations, and 9 LORAN-C monitor stations.

Regulation and administration of bridges over navigable waters is a new program for the Coast Guard. It includes regulation and administration of bridge operation and design and provides for expenditure of Federal funds to alter obstructive bridges. These functions formerly were performed by the Corps of Engineers.

C. Law Enforcement

The Coast Guard enforces all U.S. laws in U.S. navigable waters, including navigation, customs,

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[20] Functions of the Coast Guard date back to Act of August 4, 1790. Present functions were authorized by Act of August 4, 1949, 63 Stat. 495, 14 U.S.C.

[21] P.L. 89-670, Oct. 15, 1966, 80 Stat. 1.

[22] P.L. 87-396, Oct. 5, 1961, 75 Stat. 827, 14 U.S.C. 94.

[23] *Boating Statistics,* U.S.C.G. Publication 357.

criminal, conservation, pollution, and boating laws. Major Coast Guard law enforcement efforts aside from port security and recreational boating are oil pollution and conservation. In the former the Coast Guard assists the Federal Water Pollution Control Administration in enforcing the Oil Pollution Act of 1924[24] and administering the Oil Pollution Act of 1961.[25]

D. Port Security

In the Marine Port Safety Program, the Coast Guard prescribes minimal safety standards for piers and waterfront facilities handling hazardous materials. Further, the Coast Guard prescribes handling, stowage, storage, and transportation of such materials on vessels utilizing U.S. marine channels and harbors.

Coast Guard Captains of the Port, located in 55 U.S. ports, control the movement of vessels within navigable waters by requiring 24 hours advance notice of arrival at a seaport; control traffic on certain waterways; and escort vessels possessing high hazard to ports and waters.

Plans of vessels, foreign and domestic, specially constructed to carry bulk chemicals which pose a "potential unusual risk" to U.S. ports are examined by the Coast Guard, and operation in U.S. waters is fully controlled.

E. Recreational Boating

The Coast Guard administers the Federal Boating Acts of 1940 and 1958, including regulation, safety patrols, cooperation with States, and educational programs. The Coast Guard Auxiliary is a volunteer non-military organization sponsored by the Coast Guard to participate in Boating Safety Programs.

F. Icebreaking

The Coast Guard is charged with icebreaking services to support marine commerce and National defense. All major Atlantic waterways and harbors north of the Chesapeake Bay, the Great Lakes, and Alaska usually require icebreaking services each winter. Coast Guard harbor craft and coastal vessels are especially constructed for such capabilities. One major icebreaker is stationed permanently on the Great Lakes and another in Alaska, and polar icebreakers are assigned to the Great Lakes and Alaska seasonally as conditions require.

Current funding in Coast Guard coastal programs is:

	FY 68	*FY 69*
	(millions of dollars)	
Merchant marine safety	7.6	8.7
Recreational boating safety	4.5	5.5
Aids to navigation	77.2	76.3
Port safety	12.4	13.3
National search and rescue	119.0	112.9
Marine law enforcement	6.1	6.1
Water pollution control	0.8	2.3
Coastal oceanography	1.2	0.6
Total	287.8	272.5

Future programs envisioned by the Coast Guard include:

–Oil pollution abatement projects for containment, source control and recovery of massive oil spills

–Port advisory services to improve control of shipping and navigation in high-density ports

–Hazardous cargo information center for technical information on cargoes moving in water transportation

–All weather high precision coastal and harbor navigation system.

XV. ST. LAWRENCE SEAWAY DEVELOPMENT CORPORATION

The Seaway Corporation is a Government-owned enterprise under supervision of the Department of Transportation. It is authorized to construct, maintain, and operate in U.S. territory deep water navigation works in the International Rapids section as well as dredging in the Thousand Islands section of the St. Lawrence River.

It was established by the Act of May 13, 1954[26] and works in close coordination with the

[24] 33 U.S.C. 431 *et seq.* See Chapter 9.

[25] P.L. 87-167 (as amended), 33 U.S.C. 1001-1015. This Act implements the International Convention for the Prevention of the Pollution of the Sea by Oil, 1954.

[26] 68 Stat. 92, 33 U.S.C. 981.

St. Lawrence Seaway Authority of Canada in maintaining and operating the St. Lawrence Seaway. Its activities are coordinated with the Hydroelectric Power Commission of Ontario, and the Power Authority of the State of New York, which have constructed and operate power facilities in connection with development of the St. Lawrence.

The Corporation is self supporting through tolls. For 1969 the Corporation's total revenue is estimated at $7.4 million.

Current funding by the Corporation is:

	FY 68	*FY 69*
	(millions of dollars)	
Operation and maintenance	2.2	2.4
New construction	2.9	8.1
Total	5.1	10.5

XVI. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE (HEW)

A primary mission of HEW is to protect the health of the Nation's people.

Principal activities of HEW and the Public Health Service related to the coastal zone are:

–Conducting and supporting research, development, field investigations, demonstrations, and pilot operations

–Conducting studies on the role of water, aquatic plants, and animals in health, including nutritional resources

–Assisting State and local governments and providing financial assistance to their programs

–Endorsing shellfish sanitation programs

–Assisting in manpower training

–Developing health standards for seafood growing areas

–Cooperating with other Federal agencies on sea resource programs and assisting other nations in their efforts.

Major marine facilities recently established by HEW are the Marine Health Sciences Laboratories in Rhode Island, Alabama, and Washington. These are to provide a multi-disciplinary approach to many of the public health problems associated with exploitation of the estuary; in part, the Continental Shelf, for the production of shellfish and other marine foods; and a better understanding of biological and oceanographic factors influencing the marine environment public health quality. Department funding for coastal zone activities includes:

	FY 68 Actual	*FY 69 Estimate*
	(millions of dollars)	
Use of marine life in biomedical research	2.40	2.65
Health problems related to marine pollution	.90	.90
Nutritional and health aspects of marine foods	1.10	1.25
Total	4.40	4.80

Future programs recommended by the Department are:

–An innovative initiative on shellfish sanitation

–Health hazards arising from toxic chemicals pollution of coastal zone waters

–Establishment of an intra-Departmental organizational for the marine health sciences

–An innovative initiative in education for the marine sciences

–Use of the coastal zone as a source of marine forms for biomedical research

–Biomedical research on man in the sea.

XVII. DEPARTMENT OF STATE

The Department of State becomes involved in the coastal zone because of U.S. boundary waters. As a result of the treaty of 1909 with Great Britain, and various treaties with Mexico dating back to 1889, the International Joint Commission and the International Boundary and Water Commission, respectively, have been created to deal with water problems on our northern and southern boundaries.

The U.S. section of the International Boundary and Water Commission is the Federal agency responsible under the treaties of March 1, 1889, and subsequent treaties of 1905, 1933, and 1944. This section also operates under certain Congressional Acts of 1935, 1936, and 1950. Principal water related activities of the Commission deal with construction, operation, and maintenance of diversion dams, storage reservoirs, hydroelectric plants, and flood control projects along the U.S.-Mexico Rio Grande boundary.

The International Joint Commission was organized in 1911, pursuant to the treaty of Jan. 11, 1909, between the United States and Great Britain. The Commission's purpose is to prevent disputes over the use of boundary waters and settle questions arising between the United States and Canada involving rights, obligations, or interests in boundary waters. The Commission has jurisdiction over all cases involving use, obstruction, or diversion of boundary waters between the United States and Canada. Also concerned are waters flowing from boundary waters and waters at a lower level than the boundary in rivers flowing across it.

Commission approval is required to construct and maintain any works that change the natural level of boundary waters. The International Joint Commission is not an action agency, but issues reports and recommendations to the two governments dealing with such international water resource problems as the Niagara Falls beautification, Passamaquoddy tidal power project, pollution of the Great Lakes, and control of Great Lakes' water levels.

Annual State Department funding in these programs is about $1 million.

XVIII. CORPS OF ENGINEERS[27]

The Corps of Engineers, U.S. Army, has perhaps the greatest impact on the coastal zone of any Federal agency.

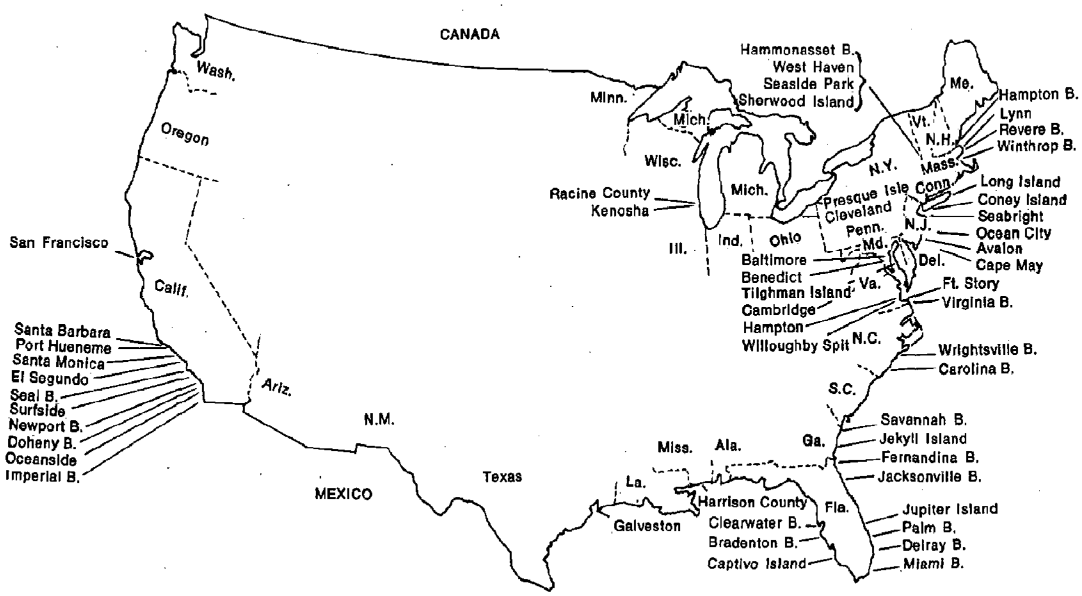

Figure 6. *Corps of Engineers demonstration projects in beach erosion control. (Source:* Information on Federal Shore Activities, *Army Corps of Engineers, Nov. 28, 1967.)*

[27]Information for this section was furnished by Brigadier General H. G. Woodbury, Jr., Director of Civil Works, Office of the Chief of Engineers to the Commission on Marine Sciences, Engineering and Resources, Oct. 9, 1967.

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Since 1824 the Corps has been responsible for navigation improvements, channels and waterways for commerce and navigation. In 1900 following the disasterous Galveston hurricane, the Corps commenced shoreline protection. And in 1930 the Corps was assigned beach erosion control.

A. Navigation Projects

The authorities, policies, and procedures pertaining to the Corps' channel and harbor program have developed over many years on the basis of many general and specific Congressional Acts. For navigation projects, Federal responsibility is limited to provision of channels, basins, and protective works; local interests are responsible for lands, terminals, and other landside appurtenances.

Except for certain small improvements, each project is specifically authorized in accordance with a long-established procedure that involves an engineering and economic determination following extensive coordination and consideration of the needs and desires of the Federal, State, and local interests concerned.

About 500 commercial harbors with depths up to 45 feet have been provided in addition to 250 harbors for small craft. About 23,000 miles of intracoastal and inland waterways have been developed. The annual waterborne commerce of the country amounts to about 1¼ billion tons having a value of about $11.5 billion.

Methods to improve navigation vary. Harbor entrances are protected by jetties or enlarged by dredging. Harbors are created by inclosing an area of open water within breakwaters, or by dredging estuaries and excavating inland areas. Rivers are improved by clearing and snagging, dredging, and the construction of locks and dams.

In addition, the Corps of Engineers administers certain Federal laws protecting and preserving U.S. navigable waters. This responsibility includes granting permits for structures over and in such navigable waters, establishing regulations for use of navigable waters, including dumping grounds, fishing areas, restricted areas, and danger zones; establishing harbor lines, and administering the Refuse Act prohibiting the disposal of refuse in coastal and other navigable waters.

In funding commercial navigation projects the Federal Government usually bears the entire construction cost of commercial navigation projects and operates and maintains them. Aids to navigation are fully Federal. Non-Federal interests are generally required to provide terminal facilities, berthing area dredging, and the necessary lands, easements, rights-of-way, and spoil disposal areas with retaining dikes and alterations or relocations of utilities where necessary.

B. Beach Erosion

Corps of Engineers activity in coastal erosion stems from the Act of July 3, 1930, which establishes the Beach Erosion Board[28] to furnish technical advice to the States on methods of providing coastal protection. By subsequent Acts, most recently the River and Harbor Act of 1962, the legislation was extended to permit the Corps of Engineers to conduct studies at Federal expense of the shores of the Atlantic and Pacific Oceans, the Gulf of Mexico, the Great Lakes, and lakes, estuaries, and bays directly connected therewith. Only those erosion problems caused principally by waves and tidal currents are eligible for study under existing law. Federal participation is limited to 50 per cent for protection of publicly owned non-Federal shores which are not park or conservation areas, and 70 per cent for park and conservation areas. Protection of Federal property may be accomplished entirely at Federal expense.

Since 1946, when Federal participation in construction was first authorized, Federal aid has been given to over 100 projects with a total cost of about $237 million, with the Federal contribution approximating $94 million.

C. Hurricane Protection

After a series of disastrous hurricanes in the early 1950's, in 1955 Congress expanded the Corps Civil Works mission by authorizing a study of hurricane protection problems on the Atlantic and Gulf seaboards. The Flood Control Act of 1958 authorized the first three recommended hurricane protection projects with the requirement that non-Federal interests assume 30 per cent of the cost. Hurricane protection reports have been the basis for Congressional authorizations totaling an estimated $361 million. Additional projects are

[28] In November 1963 the Beach Erosion Board was disestablished and replaced by the Coastal Engineering Research Center.

Figure 7. *U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi. (U.S. Army Corps of Engineers photo)*

under study, including protection of large contiguous areas of the Gulf coastline.

D. Lake Survey

Within the Corps of Engineers, the U.S. Lake Survey conducts the program of field surveys and prepares, revises, and distributes navigation charts of the Great Lakes and their outflow rivers, including bound volumes of large-scale charts primarily for recreational use. The Great Lakes Pilot and seven monthly supplements, publications which complement chart information, are issued. Continuing investigations on applied hydraulics and hydrology of the Great Lakes as well as a program on Great Lakes water resources are being conducted.

Figure 8. *Hydraulic model research at the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. (U.S. Army Corps of Engineers photo)*

The Lake Survey includes river discharge measurements, water level data collection, and the provision of consulting engineer services to various international boards and committees. Appropriate data are prepared for publication of the Lake Survey's Monthly Bulletin of Lake Levels and related material.

Major Corps facilities for coastal research are the Coastal Engineering and Research Center, Washington, D.C., and the Waterways Experiment Station at Vicksburg, Mississippi.

Funding by the Corps of Engineers is distributed as follows:

	FY 68 Actual	FY 69 Estimate
	(millions of dollars)	
Total civil works program	1,304	1,218
Coastal zone component	196	183
Planning, design, construction (including real estate), operation, and maintenance, excluding portion allocated below	187.1	173.8
Research and other Scientific activities	8.9	9.2
Suballocation of research and other scientific activities to major purpose		
Transportation		
Channel and harbor development and protection	2.919	2.7
Development and conservation of the coastal zone		
Shore stabilization and protection		
Beach erosion control and hurricane storm surge protection	1.496	1.5
Marine pollution management		
Pollution and flushing of bays, estuaries, and the Great Lakes	1.659	2.2
Recreation and conservation		
Recreation beaches and small-craft harbors	1.480	1.5
Environmental observation and prediction services	.313	0.3
Ocean exploration, mapping, charting, and geodesy	.838	0.8
National data centers		
National Oceanographic Data Center	.024	0.03
Great Lakes Data Center	.164	0.2
Total	8.893	9.2

Future programs in the coastal zone proposed by the Corps include:

–*Effects of construction activities on the ecology of the coastal zone,* a multi-agency, multi-discipline research program to suggest practical measures, related to construction, to improve the management of our estuarine and coastal waters and adjacent lands

–*Development of offshore facilities,* a research program to develop engineering design criteria and techniques for construction of future offshore barriers, islands, causeways, airfields, power and desalinization plants, harbors, floating breakwaters, terminal platforms, and access tunnels

–*New techniques and equipment for restoration of coastal shores and beaches,* a proposal to develop techniques and equipment to excavate material from offshore deposits and deliver it in a practicable and economical manner to beaches requiring restoration or nourishment.

XIX. NAVY

The effect on the coastal zone of the many activities of the Navy is difficult to ascribe. In general, the following can be noted:

–Use of the shoreline and nearshore waters for bases, test ranges, and operating areas

–Research, technology, development, and operations by Naval activities supporting the Navy's mission for National security

–Funding and other Navy support for basic science and research conducted at universities and private laboratories.

Few coastal regions do not in some measure feel the impact of Naval installations and bases. Approximately 1 per cent of the total U.S. shoreline[29] is utilized by the Department of

[29] Shoreline Recreation Resources of the United States ORRRC Report No. 4, 1962. See Table 2 of Chapter 3. Alaska and Hawaii are not included in this figure.

Defense for bases or restricted firing or test ranges, and about .06 per cent of the Continental Shelf is restricted to naval firing, explosives dumpling, submarine transit lanes, or other military use.[30]

As a policy matter, the Secretary of the Navy has required that maximum effort be made to incorporate environmental pollution preventive measures in ships and bases. To this end, he has instructed the Navy to cooperate fully with the Federal Water Pollution Control Administration and the Department of Health, Education and Welfare to comply with published standards and criteria relating to pollution abatement by Federal activities and the directives of Executive Order 11288 for the prevention, control, and abatement of water pollution by Federal activities.

Naval activities have provided extensive information concerning nearshore waters, particularly the Continental Shelf, via mapping, charting, magnetic and gravity surveys, and "man-in-the-sea," "sea lab," and deep submergence rescue programs.

Within the Navy the functions of marine science and development are directed by the Oceanographer of the Navy, under whom the principal agency is the Naval Oceanographic Office. In this activity, the basic coastal undertaking is the Nearshore Environmental Prediction System Project to predict unknown nearshore oceanographic conditions such as bottom materials by inference from known environmental conditions.

Naval engineering and technological activities are more thoroughly described in the Marine Engineering and Technology Report.[31]

The Office of Naval Research supports programs at universities and independent and some industrial laboratories. Approximately 40 per cent of all basic marine science is supported by the Navy. Projects in the coastal zone include sedimentation, seismology sound propagation, waves, coastal currents, topography, submarine canyons and other coastal features, and other studies.

Laboratories and universities where Navy supported work is being conducted is shown on Figure 9.[32]

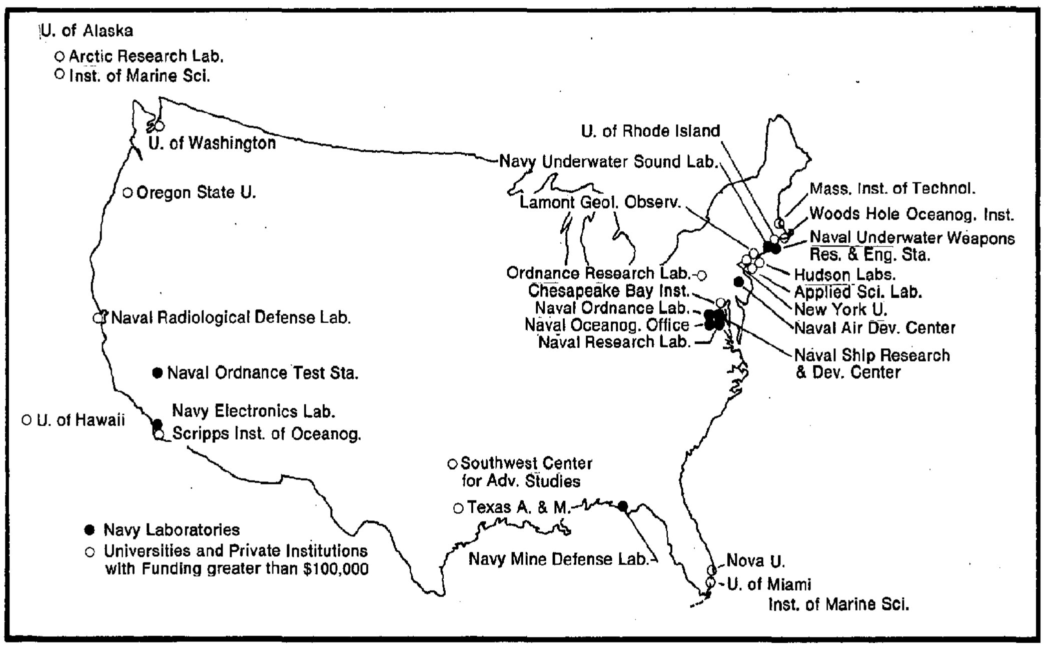

Figure 9. *Locations of major Navy laboratories and Navy-supported universities and private institutions.*

[30]This figure is obtained by measuring on 1,100 and 1,200 series USC&GS charts "prohibited" and "restricted" areas and submarine transit lanes inside the 100-fathom depth contour. Alaska and the Great Lakes are not included.

[31]Report of the Panel on Marine Engineering and Technology of the Commission on Marine Science, Engineering and Resources.

[32]From *Ocean Science Program,* Office of the Oceanographer of the Navy, June 1967.

Funding by the Navy in programs and projects directly related to the Coastal Zone is difficult to separate from other funding. The best estimates which are available are:

	FY 68	*FY 69*
	(millions of dollars)	
Great Lakes	0.1	0.1
Estuaries	2.2	2.8
Continental Shelf	12.8	12.3
Total	15.1	15.2

XX. SMITHSONIAN INSTITUTION

The Smithsonian Institution was established in 1846 to increase and disseminate knowledge. It soon became involved in research and now has research facilities in many phases of the sciences. Projects sponsored and conducted by the Smithsonian contribute significantly to coastal zone science, particularly in the fields of biology and geology.

Unique among Government activities, the Smithsonian is a private organization operating on both public and private funds. First Federal appropriation for Smithsonian operation took place in 1877.

The U.S. National Museum, of which the Museum of Natural History is a part, is the official repository of natural history materials for the U.S. Government. Over many years sections of the National Museum have acquired critical collections of catalogued marine organisms and fossils. Successions of scholar-curators have made the Institution the study and referee center for marine biologists of the world. Exchanges with scholars and institutions throughout the world have increased, and demands for information have grown beyond anticipation. In particular, requirements of the applied and engineering sciences have grown.

Facilities significant to the coastal zone operate by the Smithsonian in addition to the National Museum are:

–The Tropical Research Institute, Barro Colorado Island in the Panama Canal Zone, contains two marine biology laboratories on the Caribbean and Pacific sides of the Isthmus

–The Chesapeake Bay Center for Field Biology, a new facility to conduct estuarine research, primarily in ecology

–The Oceanographic Sorting Center, Washington, established December 1962 to act as a service organization to the scientific community in receiving, sorting, recording, and distributing marine biological and geological specimens.

Current funding by the Smithsonian Institution for programs directly related to the coastal zone:

FY 68	$175,000
FY 69	$190,000

Projects the Smithsonian plans to participate in:

–Interoceanic canal studies

–Marine preserves (principally coral atolls)

–Submersibles

–Great Lakes ecology

–Aquaculture station (Canal Zone)

–Underwater archeology.

XXI. NATIONAL SCIENCE FOUNDATION (NSF)

Created by the National Science Foundation Act of 1950,[33] NSF's fundamental purpose is to strengthen basic U.S. scientific research and education. NSF also administers the Sea Grant College and Program Act of 1966.[34]

NSF is authorized and directed to develop and encourage National policies promoting basic research and education in the sciences and to support basic research and programs to strengthen scientific research potential. The Foundation is authorized to support allied research in the field of National defense when so requested by the Secretary of Defense, in sea grant programs, and in weather modification. The Foundation also is empowered to award scholarships and fellowships for scientific studies, maintain a roster of the Nation's scientists, and promote the interchange and dissemination of scientific and technical information by a wide variety of means.

Within the coastal regime the Foundation supports, principally, research in marine biology,

[33]64 Stat. 149; 42 U.S.C. 1861-1879.

[34]P.L. 89-688, Oct. 15, 1966, 80 Stat. 998, 33 U.S.C. 1121-1124.

Table 2
INSTITUTIONAL SUPPORT BY NATIONAL SCIENCE FOUNDATION COASTAL ZONE PROJECTS

Institution	Type of Oceanographic Research Facility
University of California (Scripps)	Hydrodynamic Lab Construction
Johns Hopkins University	Research Lab Construction
New York University	Pier Construction
Oregon State University	Research Lab Construction
University of Washington	Research Lab Construction
University of Rhode Island	Research Lab Construction
Columbia University (Lamont)	Sediment Lab Construction
University of Miami	Biology Lab Construction
University of California (Scripps)	Pier Facility and Biology Lab Construction
University of Miami	Physical Lab Construction
University of Hawaii	Biology Lab Construction
Naples Zoological Station	Biology Lab Construction
University of California (Berkeley)	Biology Lab Construction
University of California (Santa Barbara)	Biology Lab Construction
Communications Research Institute	Biology Lab Construction
New York Aquarium	Biology Lab Construction
California Institute of Technology	Biology Lab Construction
University of Connecticut	Biology Lab Construction
Marine Biological Laboratory	Biology Lab & Pier Construction
University of Puerto Rico	Biology Lab Renovation
University of Miami	Biology Lab Renovation
Duke University	Biology Lab Expansion
University of Texas	Mooring Facilities & Lab Modification
Bermuda Biological Station	Biology Lab Modification & Expansion
Columbia University (Lamont)	Machine & Instrument Shop Construction
University of Washington	Biology Lab Expansion
Cape Haze Marine Laboratory	Biology Lab Modification
Stanford University	Biology Lab Modification & Construction
Massachusetts Institute of Technology	Physical Lab Expansion
University of Miami	Biology Lab Modification
Columbia University (Lamont)	Biology Lab Construction
Woods Hole Oceanographic Institute	Biology & Chemical Lab Construction
University of Hawaii	Institute of Geophysics Construction
Texas A&M University (Galveston Lab)	Research Lab Modification
Florida State University	Arctic Sediment Core Laboratory
Columbia University (Lamont)	Electron Microscope Laboratory

geology, and pollution. It also gives grants for laboratory facility and ship construction. Approximately 40 per cent of all support to institutions for research in marine sciences comes from the Foundation. Current funding in coastal zone projects is about $3.4 million out of total marine sciences funding of about $30 million.[35]

[35]Figures provided at Panel hearings, with National Science Foundation, Oct. 10, 1968.

The NSF is an important source of support to institutions for the acquisition and construction of facilities.

Table 2 lists institutions and the general types of facilities the Foundation has supported the past few years, and at which coastal research is conducted:

The Sea Grant Program administered by the Foundation is intended as a means of involving scholars and academic institutions in the practical problems of marine resource development. The Sea Grant Program began in 1968 with funding of $4 million, most for research within the coastal zone. The program can be expected to become a most important source of funding for coastal environment research.

A summary of estimated funding for research directly related to the coastal zone is:

	FY 68	FY 69
	(millions of dollars)	
Basic research[36]	3.4	3.4
Sea Grant	3.0	3.0
Total	6.4	6.4

XXII. WATER RESOURCES COUNCIL

The Water Resources Council is an independent agency established by the Water Resources Planning Act of 1965[37] and is composed of the Secretaries of Agriculture; Army; Health, Education and Welfare; Interior; and Transportation; and the Chairman of the Federal Power Commission. The Council has primary responsibilities for continuing studies and periodic assessments of the adequacy of U.S. water supplies; for maintaining a continuing study of the relation of regional or river basin plans to the requirements of larger regions of the Nation; for appraising adequacy of Federal programs; and for recommendations to the President regarding Federal policies and programs.

The Council is to establish principles, standards, and procedures for Federal participation in preparing comprehensive regional or river basin plans and for formulating and evaluating Federal water and related land resource projects.

On Nov. 29, 1967, the Council adopted a statement clarifying that coastal, lake, and river shorelines and islands are integral parts of the planning activities of the Council, river basin commissions, and other field organizations and State programs under the Water Resources Planning Act.

River basin commissions established under the Act having coastal zones are the Pacific Northwest, the Great Lakes, and New England. In each commission a chairman has been appointed by the President and a small staff is being organized. The established commissions include 16 of the 28 States with coastal zones.

The Council recommends that River Basin Commissions be considered for the remaining States having coastal zones.

The Council makes grants to States for comprehensive planning regarding State waters and related land resources. In 1968 the Council granted $300,000 to South Carolina to plan development and management of tidelands and coastal waters.

XXIII. ATOMIC ENERGY COMMISSION (AEC)

The AEC was established by the Atomic Energy Act of 1946, as amended by the Atomic Energy Act of 1954.

The AEC's principal purpose is to provide National policy for development, use, and control of atomic energy. Its primary responsibilities involving the marine environment relate to (1) control of radioactive emissions to prevent danger to public health, (2) investigations, (3) research, and (4) regulations preparatory to construction of combined desalting and power generation plants.

The Commission makes grants and contracts supporting environmental health and sciences, most for research concerning occurrence, effects, and dispersal of radioactive fallout, wastes and pollutants.

Current funding in the coastal zone is:

	FY 68	FY 69
	(millions of dollars)	
Estuaries	0.3	0.3
Continental Shelf	2.0	2.0
Total	2.3	2.3

The growing number of nuclear power plants concerns the AEC from the standpoint of construction and operation licensing. Operable or

[36] NSF grants for institutional support and other research and training operations are not separately available for the coastal zone. Therefore this figure may not accurately reflect all NSF supported activity within the coastal regions. If such were included, the figure might better be approximated at $10 million. This would result in a total of $13 million versus $6.4 million current funding in the coastal zone.

[37] Public Law 89-80, July 22, 1965. Title II of this law authorized the establishment of river basin commissions to conduct regional planning of water and related land resources.

planned facilities are shown on Figure 9 of Chapter 4.

The AEC now licenses nuclear plants from the standpoint of radioactive safety only. Many activities concerned with the effects of water diversion and thermal addition believe that these aspects should also be included.

Nuclear power and desalinization plants are envisioned on the Continental Shelf underwater.

XXIV. FEDERAL POWER COMMISSION (FPC)

The FPC is an independent agency created by the Federal Water Power Act of June 10, 1920 (41 Stat. 1063, 16 U.S.C. 791-823), to investigate water and power development of U.S. rivers and to issue licenses for non-Federal development thereof. Additional responsibilities have been assigned under other legislation and by Executive Order.

The FPC issues licenses for constructing and operating non-Federal hydroelectric power projects on U.S. public lands or navigable waters. The Commission reviews proposed dams to be constructed by the Department of the Army, the Department of the Interior, or other Federal agencies and makes recommendations concerning the installation of facilities for hydroelectric power development. It assesses headwater benefit charges against owners of non-Federal water power projects directly benefited by upstream improvements constructed by the United States, its licensees or permittees.

Under provisions of the Fish and Wildlife Coordination Act, the FPC must consult with the Fish and Wildlife Service on effects on wildlife of any proposed water diversion.

XXV. STATE ACTIVITY

Extensive planning programs for coastal conservation and management are under way in many States, notably California, Oregon, Maryland, North Carolina, and Florida. The California program involves San Francisco Bay and includes interim permit controls over dredging and filling during the planning period; its 23 research and planning studies are budgeted at nearly one-quarter million dollars a year for several years.[38]

[38] See Appendix D.

A common denominator of regulation in most States is participation in Corps of Engineers navigation permit proceedings, general water pollution control laws, fish and game regulations, and some controls exercised in conjunction with disposal or lease of State-owned underwater lands.

Legislative controls beyond these routine features include:

–Permit requirements for dredging, filling, and other alterations in coastal wetlands (Massachusetts, Maine, New Hampshire, North Carolina, and Rhode Island). These laws usually go beyond the Corps of Engineers permits and State lands controls, in that the wetlands permits apply to privately owned uplands, not merely to State-owned lands and lands under navigable waters. In Massachusetts, the wetlands controls are accompanied by power to condemn lands if a "taking" is involved. In addition to its permit law, Massachusetts has enacted a related statute that permits a "rule-making" approach, authorizing adoption of regulations to control wetlands alteration on a regional basis.

–Establishment of bulkhead lines to control leasing (Texas) or dredging and filling (Florida).

–As previously noted, interim permit controls over dredging and filling of coastal marshlands have been adopted by a regional agency in California, to forestall development during the planning period of the agency's program.

–Some effort has been made to use local zoning machinery for coastal marshland preservation. As indicated elsewhere in this report though, these efforts have encountered serious legal obstacles in more than one State. Delaware has reflected on its Comprehensive Plan Map some coastal wetlands for conservation purposes, but the plan has not been implemented by zoning.

North Carolina, Connecticut, and New York have the legislative authority to condemn estuarine lands. Most State programs, however, must rely on voluntary acquisition.

While acquisition for estuarine conservation has been conducted only on a limited scale in most coastal States, extensive programs involving thousands of acres are under way or being planned in several States.

States planning substantial acquisitions include New Jersey, California, Maine, Connecticut, Rhode Island, and Delaware. State acquisition is often supplemented by acquisition by private conservation groups and Federal agencies.

New York has pioneered under the Long Island Wetlands Act a program of State-local cooperation. This provides for State cost sharing in maintenance, operation, and development of locally-owned wetlands dedicated to conservation purposes.

Low funding levels for land acquisition or regulation programs have often hampered State estuarine conservation activities, but there are exceptions. For example, Maine has spent $5 million for park lands plus $20,000 annually for waterfowl wetlands. Connecticut is spending about $500,000 for acquisition in the current biennium. California's planning budget has been substantial—almost one-quarter million dollars annually for several years. Passage of a multi-million-dollar Green Acres bond issue by New Jersey voters in 1964 has resulted in large State salt-marsh acquisitions. In other States substantial operating and acquisition budgets may evolve for some programs now in the planning stage. Use of U.S. land and water conservation funds or estuarine acquisitions represents a significant funding source potential.

A diversity of administering agencies exists. In Massachusetts, New York, and Rhode Island there is coordinated administration by several operating divisions of a single natural resources department, though with some local participation in control decisions. In most other States administration is divided among several agencies. Combined boards, such as the Maine Wetlands Control Board, in several New England States make decisions on permits for wetland alteration or state land leasing.

Little formal provision apparently exists for coordinated development and conservation, except by boards with diverse representation (such as the wetlands control boards) or in the exceptional case where all affected program interests are concentrated within a single State department. The general pattern is one of informal coordination among affected agencies.

A detailed survey of State activities was conducted by the Institute of Public Administration under contract to the Commission and the report is available separately.[39]

A brief summary of State activities is shown in Appendix D.

[39] See footnote 1.

The juncture of land and sea has, from antiquity, been an area of uncertain boundaries, subject to imprecise rules, reflective of the natural forces of the tides, and geared to the needs of commerce, navigation, fisheries, and land usage tolerant of imprecision and relatively free of diverse uses.

The principles on which we base ownership date back at least to Magna Carta, and have been subject to a variety of interpretations in U.S. State and Federal courts. These interpretations stem from the common law principle that both the title and dominion of rivers and arms of the sea, where the tide ebbs and flows, and all the lands below the high water mark, are in the sovereign.

Boundaries determined by tidal ebb and flow are not unambiguous, time-invariant lines, but a condition at the water's edge during a particular instant of the tidal cycle. Ownership of the sovereign of the navigable waters bordering our coasts generally is subject for the benefit of its citizens to a public trust for navigation, commerce, and fishing.

The public trust also provides a rationale for public regulation regardless of ownership, but it has not proven to be an effective restraint upon the indiscriminate sale or disposal of tidelands. And as we become aware of the value of marshland tidelands for biological, recreational, and aesthetic purposes, in addition to reclamation as upland, the public trust under the common law often proves inadequate in conserving such areas where desirable. Legislation has had to be enacted and administrative action taken to meet the new diverse uses of areas formerly considered waste lands.

Technological capabilities, coupled with the discovery of rich mineral resources in some tidelands and submerged areas of the coastal United States, have heightened the conflicts between the States and the Federal Government, and have led to extensive major litigation and enactment of the Submerged Lands Act by which title to the bed and natural resources of the territorial sea within their boundaries was granted by Congress to the States.

While the Submerged Lands Act clarified some matters, it left to the courts major boundary and ownership questions still to be resolved. In the

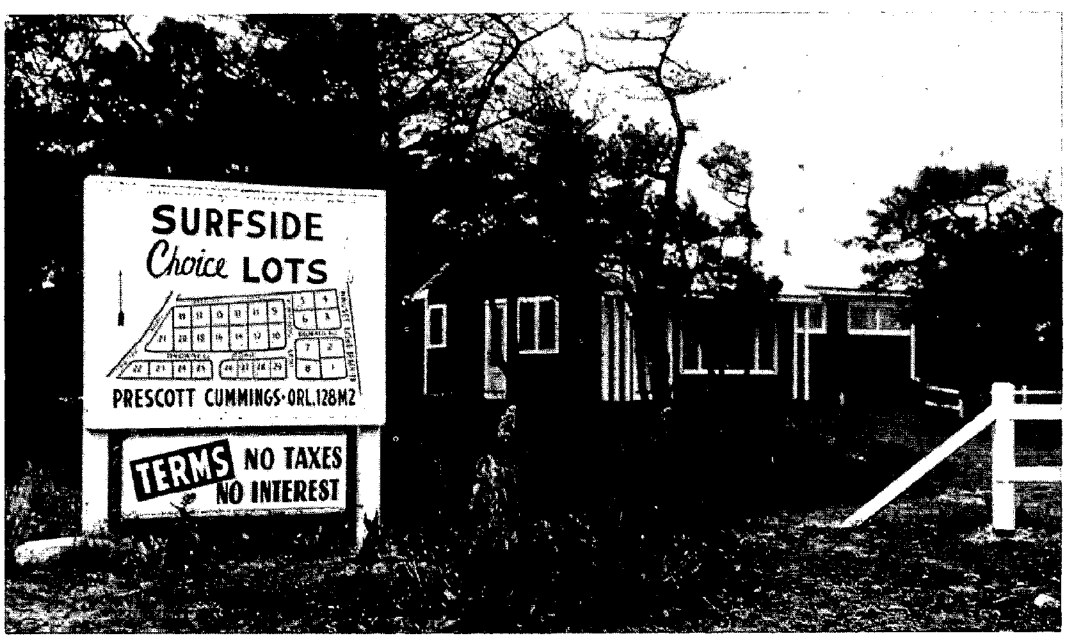

Figure 1. *Widespread and often unregulated land development has resulted in a general demand for more public control of the shoreline. (National Park Service photo)*

context of increasingly diverse and conflicting uses of the coastal zone, questions of boundaries and ownership are discussed in Section 1 of this chapter.

Conservation and development are inseparable parts of the same planning and regulatory challenge facing the National, State and local governments in the coastal zone. Consideration must be given to both land uses and water uses in considering coastal zone planning and regulatory techniques.

Land uses produce many coastal zone environmental problems: domestic and commercial sewage, waste disposal, filling of marshlands or water areas for housing, commercial businesses, and airports, to name a few.

Land use regulation has developed to a sophisticated art, generally administered by local government. In a few States, such as Hawaii, Connecticut, and Wisconsin, State-wide zoning statutes exist for limited purposes relating to land use and the water environment. With increased awareness and consideration of the marine environment for health, recreational, ecological, aesthetic, and psychological purposes, the limitations of local government in providing adequate planning and regulatory practices become increasingly pronounced, and concepts of regional or State-wide government become desirable or necessary.

Section II of this chapter is devoted to regulatory authority of States and local governments. It discusses the limitations on regulation, regulatory efforts used in the past, and regulatory proposals to meet a variety of new needs.

I. BOUNDARIES AND OWNERSHIP

A. Coastal Boundaries

The uncertainty in our law of shore boundaries derives partly from reliance on the natural phenomenon of the tides. As stated by Aaron Shalowitz:

The phenomenon of the tide is far from being a simple one. The tidal effect of sun and moon upon the waters of the earth depends upon the relative positions of the three bodies at a particular time and a particular place. Considering then that the earth revolves on its axis once every 24 hours, and its journey around the sun takes one year; that the moon revolves around the earth once every 29½ days, and its orbit is inclined on the average of 23½° to the earth's equator; that every body of water has its own period of oscillation, and responds differently to the tide-producing forces; and that all of these factors, together with the configuration of the land bordering the water areas, enter into the formation of the tide, there is present almost limitless possible combinations into which these factors can unite to produce both differences at the same time at different places and differences at the same place at different times.[1]

In addition to the tides, the sea level varies with atmospheric pressure and ocean current changes.

Boundaries determined by the tides are not unambiguous, time-invariant lines, but are a condition at the water's edge during a particular instant of the tidal cycle:

Boundaries determined by the course of the tides involve two engineering aspects: a vertical one, predicated on the height reached by the tide during its vertical rise and fall, and constituting a tidal plane or datum, such as mean high water, mean low water, etc.; and a horizontal one, related to the line where the tidal plane intersects the shore to form the tidal boundary desired, for example, mean high-water mark, mean low-water mark. The first is derived from tidal observations alone, and once derived (on the basis of long-term observation), is for all practical purposes a permanent one. The second is dependent on the first, but is also affected by the natural processes of erosion and

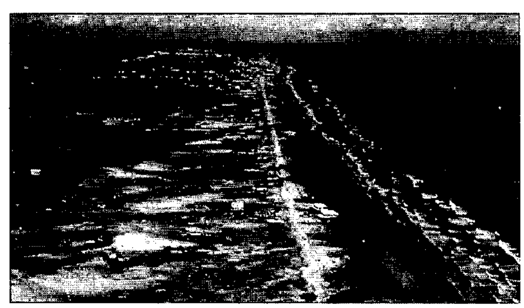

Figure 2. *The natural shoreline along the Gulf Coast as shown here at Grand Isle, Louisiana, is difficult to delineate when valuable oil leases are at stake. (U.S. Army Corps of Engineers photo)*

[1]Shalowitz, 1 Shore and Sea Boundaries 84-85 (1962).

accretion, and the artificial changes made by man....[2]

State ownership of tidelands derives from English common law.[3] However, English cases were not precise as to exact location of the upper boundary of tideland, and not until 1854, in the case of *Attorney-General* v. *Chambers*[4] did the English courts define "ordinary" high water as "the line of the medium high tide between the springs and the neaps," which is a close approximation of the rule later laid down by the United States Supreme Court when it definitively established the Federal rule for interpretation of the term "ordinary high water mark," in *Borax Consolidated, Ltd.* v. *Los Angeles.*[5] In the *Borax Consolidated* case, the Court said that "it is necessary to take the mean high tide line, which ... is neither the spring tide nor the neap tide, but a mean of all the high tides."[6] In so defining the ordinary high water mark, the Court chose a test recommended by the U.S. Coast and Geodetic Survey, and rejected the tests used in a number of States.[7] Certain recent State cases, however, have adopted the Federal rule.[8]

A third interpretation of "mean high tide line" is the vegetation line, such as found in the State of Washington:

The line of ordinary high tide is that line which the water impresses on the soil by covering it for sufficient periods to deprive the soil of vegetation and destroy its value for agricultural purposes.[9]

Although some States do not make the distinction, the line-of-vegetation rule is properly applicable only to nontidal waters, where no absolute high-water level can be established.[10] Other variations on determination of the high water mark are found in Louisiana, where the boundary is the line reached by the highest winter tide,[11] and those parts of Texas covered by Spanish land grants, where the line is that of mean higher high tide.[12]

The adoption of different rules for determining the "ordinary" high tide means that in those States that follow the common law rule that private property extends only to the "ordinary high water mark" there may be a substantial difference between the boundary that would be found under the Federal rule and that found under a different State rule. However, where the prior sovereign has not created private titles, and the State was created from Federal territory, the coastal boundary will be determined by the Federal rule unless the State chooses to adopt a rule more generous to the upland owner than the Federal rule.

Assuming continued reliance upon the tides in order to determine shore boundaries, the Federal rule in the *Borax Consolidated* case appears to be the most precise and accurate method available. While the Federal test is applied in determining the boundaries of Federal grants, we believe there is much value to be gained by the States in adopting the test in controversies between the States and private interests.

B. Tidelands Ownership

At common law, the sovereign owned tidelands and lands under navigable waters and his (its) title stopped at the line of ordinary high water, as modified from time to time by gradual accretion, erosion, or reliction. When the Union was created, sovereignty was divided between the States and the Nation. The States retained ownership of the

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[2] Shalowitz, *op. cit.*, p. 89.

[3] See *Shively* v. *Bowlby*, 152 U.S. 1, 57-58 (1893).

[4] 4 DeG., M & G 206, 217-218, 43 Eng. Reps. 486, 490 (1854).

[5] 296 U.S. 10 (1935).

[6] 296 U.S. at 26.

[7] E.g., *Tischemacher* v. *Thompson*, 18 Cal. 11, 21 (1861); *Otey* v. *Carmel Sanitary District*, 219 Cal. 310, 26 P. 2d 308, 310 (1933); *People* v. *William Kent Estate Co.*, 51 Cal. Rep. 215, 219, 242 C.A. 2d, 156 (Ct. App., 1st Dist., 1966); *Miller* v. *Bay-to-Gulf, Inc.*, 141 Fla. 452, 193 So. 425, 428 (1940); *Narrows Realty Co. Inc.* v. *State of Washington*, 52 Wash. 2d 843, 329 P. 2d 836, 837 (1958).

[8] Cf. *O'Neill* v. *State Highway Department of New Jersey*, 50 N.J. 307, 235 A. 2d 1, 9 (1967). The Supreme Court recently followed the *Borax Consolidated case in Hughes* v. *Washington*, 389 U.S. 290 (1967). See also *United States* v. *Washington*, 294 F. 2d 830 (1961), *cert. denied*, 369 U.S. 290.

[9] *Harkins* v. *Del Pozzi*, 50 Wash. 237, 310 P. 2d 532, 534 (1957). See also *Shelton Logging Co.* v. *Gosser*, 26 Wash. 126, 66 Pac. 151 (1901).

[10] See *Borough of Ford City* v. *United States*, 345 F. 2d 645 (C.A. 3), *cert. denied*, 382 U.S. 902.

[11] *Morgan* v. *Negodick*, 40 La. Ann. 246, 3 So. 636 (1887); La. Rev. Civ. Code, art. 451.

[12] *Luttes* v. *State*, 159 Tex. 500, 324 S.W. 2d 167, 187 (1958).

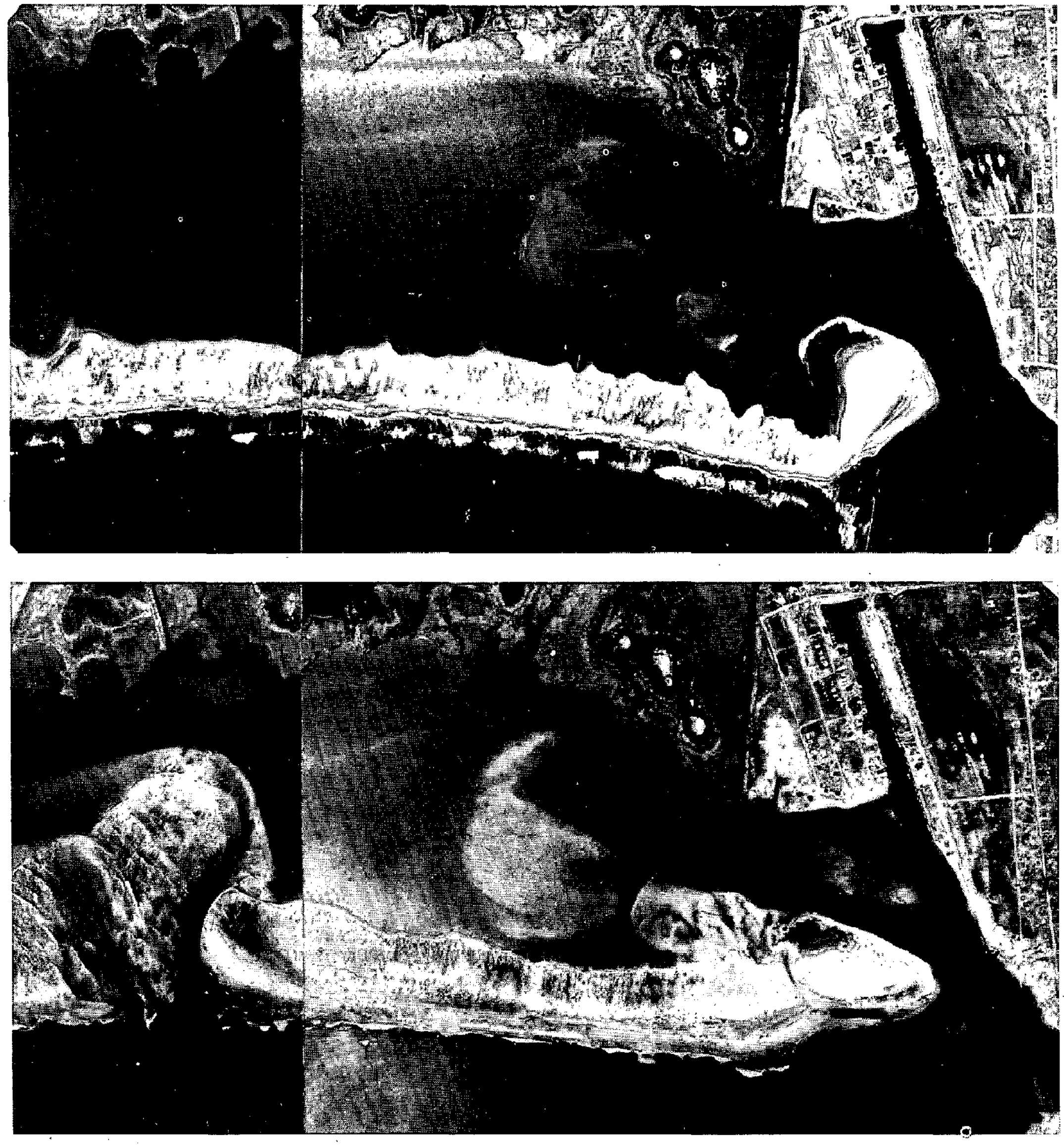

Figure 3. *A shoreline can change drastically under the effects of a storm. Here the coast of Assateague Island, Maryland, before (upper) and after (lower) the severe storm of March 6-9, 1962. Precise boundaries dependent on the shoreline become confused. (Environmental Science Services Administration Coast and Geodetic Survey photos)*

tidelands and lands under navigable waters within their boundaries as an attribute of their sovereignty. New States created thereafter entered on "equal footing" with the original 13 States, which meant that they were constitutionally entitled to not less than title to the tidelands and submerged lands within their boundaries,[13] nor more.[14] Such title is held by each State in trust for its people.[15]

[13] *Pollard's Lessee* v. *Hagan,* 3 How. 212 (1845).

[14] *United States* v. *Texas,* 339 U.S. 707, 715-18 (1950).

[15] *Martin* v. *Waddell,* 16 Pet. 367, 410 (1842); *Pollard's Lessee* v. *Hagan,* 3 How. 212 (1845); *Manchester* v. *Massachusetts,* 139 U.S. 240 (1891); *Shively* v. *Bowlby,* 152 U.S. 1 (1893); *Louisiana* v. *Mississippi,* 212 U.S. 1 (1906); *The Abby Dodge,* 223 U.S. 166 (1912); *Borax Consolidated, Ltd.* v. *Los Angeles,* 296 U.S. 10 (1935); *United States* v. *California,* 332 U.S. 19, 30 (1946); *United States* v. *California,* 381 U.S. 139 (1965). See listing in Radigan, "Jurisdiction over Submerged Lands of the Open Sea," Legislative Reference Service, Library of Congress, 82nd Cong., 1st Sess. (1951). The recent case of *Lane* v. *McEachern,* 162 S.E. 2d 174 (1968) is an example of private rights acquired through historic grant.

The public trust relates not only to ownership of tidelands and submerged lands, but also provides a rationale for public regulation of their use, regardless of ownership, which we discuss in Section II of this chapter.

Cautioning that care is necessary in applying precedents in one State to cases arising in another because there is no universal and uniform law upon the subject and that each State has dealt with the lands under the tide waters within its borders according to its own views of justice and policy, the United States Supreme Court stated in *Shively* v. *Bowlby:*

By the common law, both the title and the dominion of the sea, and of rivers and arms of the sea, where the tide ebbs and flows, and of all the lands below high water mark, within the jurisdiction of the Crown of England are in the King. Such waters, and the lands which they cover, either at all times, or at least when the tide is in, are incapable of ordinary and private occupation, cultivation and improvement; and their natural and primary uses are public in their nature, for highways of navigation and commerce, domestic and foreign, and for the purpose of fishing of all the King's subjects. Therefore the title, jus privatum, *in such lands, as of waste and unoccupied lands, belongs to the King as the sovereign; and the dominion thereof,* jus publicum, *is vested in him as the representative of the nation and for the public benefit. . . .*[16]

The Court further stated that:

the common law of England upon the subject . . . is the law of this country, except so far as it has been modified by the charters, constitutions, statutes or usages of the several colonies and states, or by the constitution and laws of the United States.[17]

"The title and rights of riparian or littoral proprietors in the soil below high water mark of navigable waters are governed by the local laws of the several States."[18] Where the Federal Government was the initial proprietor, any claim by a State or by others must derive from the Federal title;[19] the rights conveyed by a Federal patent are determined by Federal law.[20] In some cases, however, private parties may claim title by succession to concessions or grants antedating creation of the Union, and in one such case the applicable local law governing the extent of title was that of the antecedent Spanish sovereign.[21]

The States may relinquish to riparian and littoral proprietors rights which properly belong to the States in their sovereign capacity.[22] Among the 13 original States, Rhode Island, Connecticut, New York, New Jersey, North Carolina, and South Carolina followed the common law rule that the owner of land adjacent to waters in which the tides ebbed and flowed owned to the high water mark; while Massachusetts,[23] Maine,[24] New Hampshire,[25] Delaware,[26] Pennsylvania,[27] Virginia,[28] and Georgia[29] modified the common law practice to permit the upland owner to hold title to the low water mark, subject to the public rights of navigation and fishing, and certain other modifications peculiar to each State.

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[16]152 U.S. 1, 11 (1893).

[17]152 U.S. at 14.

[18]*Shively* v. *Bowlby,* 152 U.S. 1, 40 (1894); *Hardin* v. *Jordan,* 140 U.S. 371, 382; *Port of Seattle* v. *Oregon & Washington R.R.,* 255 U.S. 56, 63.

[19]*United States* v. *Grand River Dam Authority,* 363 U.S. 229, 235; *Shively* v. *Bowlby, supra,* note 18, at 50-51.

[20]*Borax Consolidated, Ltd.* v. *Los Angeles,* 296 U.S. 10, 22, and cases cited therein. Cf. *Hughes* v. *Washington,* 389 U.S. 290 (1967).

[21]*Joy* v. *St. Louis,* 201 U.S. 322 (1906).

[22]*Barney* v. *Keokuk,* 94 U.S. 324, 338 (1876).

[23]See *Michaelson* v. *Silver Beach Imp. Ass'n,* 342 Mass. 251, 173 N.E. 2d 273, 275 (1961). The ordinance itself has ceased to be in force, but the rule remains as part of the common law of Massachusetts. See 1 Farnham 193 (1904).

[24]See *Sinford* v. *Watts,* 123 Me. 230, 122 Atl. 573 (1923).

[25]See *Shively* v. *Bowlby, supra* note 18, at 20; also *Nudd* v. *Hobbs,* 17 N.H. 524, 526-27 (1845).

[26]See *State ex rel. Buckson* v. *Pennsylvania R. Co.,* 223 A. 2d 537, 597-98 (1967). This is a lower court case presently on appeal.

[27]*Wall* v. *Pittsburgh Harbor Co.,* 152 Pa. 427, 25 Atl. 647 (1893).

[28]*Taylor* v. *Commonwealth,* 102 Va. 759, 47 S.E. 875 (1904). See also Code of Virginia, 1950, §62-2.

[29]Georgia, Constitution of 1945, art. I, §6: "The Act of the General Assembly (approved Dec. 16, 1902), which extends the title of ownership of lands abutting on tidal water to low water mark is hereby ratified and confirmed."

The States follow different rules in determining ownership. Some rest title on the fact of navigability, asserting state ownership of land under navigable waters regardless of whether the tide ebbs and flows,[30] but in some jurisdictions the test of ownership in tidelands hinges on the fact of the ebb and flow of the tide.[31]

Along flat, low-lying coasts the determination of the boundary line with precision and accuracy is of considerable importance, inasmuch as in some flat areas, a difference of one inch in elevation can make a difference of several hundred feet of submerged land lost or gained at high tide, on which may hinge the revenues of substantial oil, gas, or other mineral claims.[32] The choice of test for determining the boundary also will have a substantial impact. If the definition of "mean high tide" is stated in terms of level or elevation, the title to certain interior lands not naturally reached by the mean high tide but lying below the mean high tide level might be deemed to belong to the State, as was contended by New Jersey in *O'Neill* v. *State Highway Department.*[33] The New Jersey Supreme Court rejected the State's contentions, and chose the test adopted by the United States Supreme Court in the *Borax Consolidated* case.

C. Limits of the Public Trust in Tidelands

As noted in the preceding section, tideland traditionally is held by the State in trust for its people for commerce, navigation, and fishing.[34] Among the States, however, there is no unanimity regarding the limits of the trust. In some States, navigation is the sole or principal criterion for allowing dredging or filling in tidelands.[35]

Other States have extended the trust to include public rights other than navigation, commerce, and fishing. For instance, Connecticut protects fowling and hunting, the taking of seaweed and sedge, bathing, and swimming, but these rights can be extinguished either by the exclusive occupation of the soil below high-water mark by the riparian owner, or by the paramount public right of free and unobstructed use of navigable waters for navigation.[36]

The trust concept also has been expanded by increasing recognition of park and recreational uses, and the conservation of natural resources, by the courts and particularly by certain State legislatures.[37] California permits municipalities to lease tidelands for park, recreational, residential, or educational purposes when they deem industrial uses to be inimical to the best interests of the city.[38] The State of Washington places statutory limitations on the sale of certain parts of the foreshore of the Pacific Ocean, emphasizing recreational values.[39] Florida's recent amendments to its Code are important for their precedent in recognizing conservation of natural resources as a public trust:

Any bulkhead line when so fixed or ascertained and established shall represent the line beyond which a further extension creating or filling of land or islands outward into the waters of the country shall be deemed an interference with the servitude in favor of commerce, navigation, and conservation of natural resources, with which the

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[30] *Brickell* v. *Trammell,* 77 Fla. 544, 82 So. 221; *Home Real Est. Loan and Ins. Co.* v. *Parmele,* 235 N.C. 689, 71 S.E. 2d 474 (1952); North Carolina General Statutes §146-64 (1954). Alabama, California, Mississippi, Oregon, Pennsylvania, Texas, Virginia, and Washington are among the coastal States that have followed this rule.

[31] *Bailey* v. *Driscoll,* 19 N.J. 363 (1955); *O'Neill* v. *State Highway Department of New Jersey,* 50 N.J. 307, 235 A. 2d 1 (1967). Georgia, Illinois, Maine, Maryland, Michigan, New York, and South Carolina also have followed this rule.

[32] F. J. Hortig, Executive Officer, California State Lands Commission, "Administrative and Technical Problems Related to Establishment of California Coastal and Offshore Boundaries," Third Annual Law of the Sea Institute, June 1968.

[33] 50 N.J. 307, 235 A. 2d 1, 9 (1967).

[34] *Illinois Central R.R.* v. *Illinois,* 146 U.S. 387, 452 (1892).

[35] Cf., Ala. Stats., tit. 38, §122; Del. Code Ann., tit. 23, §1507; Va. Code, §62-2.1 (1966 Supp.).

[36] *Orange* v. *Resnick,* 94 Conn. 573, 580-81, 109 Atl. 864, 866 (1920). *See also Butler* v. *Attorney-General,* 195 Mass. 79, 80 N.E. 688, 689 (1907); *Collins* v. *Gerhardt,* 237 Mich. 38, 211 N.W. 115 (1926); *Allen* v. *Allen,* 19 R.I. 114, 32 Atl. 166, 167 (1895); *Treuting* v. *Bridge and Park Commission of the City of Biloxi,* 199 So. 2d 627, 632 (Miss. 1967).

[37] *Muench* v. *Public Service Commission,* 261 Wis. 492, 511-12, 53 N.W. 2d 514, 522 (1952); California, 33 Ops. Atty. Gen. 152 (City of Long Beach permitted to use tidelands oil income to maintain and operate public beaches on granted tidelands).

[38] California Government Code, §37387.

[39] See Washington, R.C.W.A. 79.16.170-.171; Wash. Laws 1963, ch. 212; Wash. Laws. 1967, ch. 120.

navigable waters of this state are inalienably impressed.[40]

D. Limitations on Tideland Disposal

The principal limitations on tideland destruction have been (1) State constitutional or statutory limitations on their disposal and (2) protection of navigation under the Federal navigational servitude (see next section). State constitutional and statutory prohibitions on the sale of tidelands generally have many exceptions and limitations, the effect of which is shown in high percentage of loss of marsh and tidelands in recent years. For instance, California's Public Resources Code withholds tidelands from sale[41] and its constitution prohibits sale of tidelands within two miles of any incorporated city, county, or town on the waterfront of any harbor or bay used for navigation,[42] yet California has lost a larger percentage of fish and wildlife estuarine habitat than any other State in the last 20 years.[43]

Florida recently has clarified its previous law authorizing sale of tidelands by the Trustees of the Internal Improvement Fund if not "contrary to the public interest," and now requires determination of the extent to which such sale:

would interfere with the conservation of fish, marine and wildlife or other natural resources, including beaches and shores, and would result in destruction of oyster beds, clam beds or marine productivity, including, but not limited to, destruction or marine habitats, grass flats suitable as nursery or feeding grounds for marine life, and established marine soils suitable for producing plant growth of a type useful as nursery or feeding grounds for marine life, and if so, in what respect and to what extent and they shall consider any other factors affecting the public interests.[44]

The statute contemplates use of biological, ecological, and, if necessary, hydrographic studies to aid the Trustees in their determination and, furthermore, requires public hearings before sale of tidelands.

A grant of tidelands by the States does not generally extinguish public rights in them until the tidelands are so physically changed, according to the grant terms, that those rights can no longer be exercised, at which time the riparian owner's rights become absolute.[45]

However, some cases suggest that public rights in tidelands may be extinguished before the tidelands are changed physically, if lost "in promoting the interests of the public,"[46] such as adapting the land to the best use for navigation.

If in so adapting the tidelands for this use it is found necessary or advisable in any of the use to cut off portions of it from access to navigable water so that it becomes unavailable for navigation, the state has power to exclude such portions from the public use and to that extent revoke the original dedication. When this has been done in the regular administration of the trust, the land thus excluded from use for navigation may become proprietory land not subject to the public use and it may then be alienated irrevocably by the state for private use to private individuals. . . . But statutes purporting to authorize an abandonment of such public use will be carefully scanned to ascertain whether or not such was the legislative intention and that intent must be clearly expressed or necessarily implied. . . .[47]

In still other cases, where the State has granted title to tide and submerged lands subject to a public trust for certain purposes, the State may

[40] Fla. Stats. §253.122 (1967).

[41] California Public Resources Code §7991.

[42] California Constitution, art. 15, §3.

[43] See *Estuarine Areas: Hearings Before the Subcommittee on Fisheries and Wildlife Conservation of the Committee on Merchant Marine and Fisheries,* House of Representatives, 90th Cong. 1st Sess., 1967, p. 30. Similar results have occurred in the State of Washington, where its constitution forbids sale of tidelands within one mile of incorporated cities (art. XV, §1) and asserts State ownership of tidelands (art. XVII, §1) which, absent overall policy regarding use and disposal of tidelands, resulted in disposal of much State-owned land. See *Hughes* v. *State,* 67 Wash. 2d 799, 410 P. 2d 20, 23 (1966). We note, however, the recent reversal of that trend by the State legislature by its establishment of a State seashore conservation area and controls over the sale of publicly owned lands.

[44] Fla. Code, §253.12(2) (Supp. 1968).

[45] See *Atwood* v. *Hammond,* 4 Cal. 2d 31, 48 P. 2d 20, 24 (1955); *Allen* v. *Allen,* 19 R.I. 114, 132 Atl. 166 (1895); *City of Boston* v. *Richardson,* 105 Mass. 351, 362 (1870); *State* v. *Black River Phosphate Co.,* 32 Fla. 82, 13 So. 2d 640, 649 (1893); *Holland* v. *F. I. Pearce Fin. & Const. Co.,* 157 Fla. 649, 27 So. 2d 76, 81-82 (1946).

[46] See *Illinois Central R.R.* v. *Illinois,* 146 U.S. 387, 453 (1892).

[47] *People* v. *California Fish Co.,* 16 Cal. 576, 138 Pac. 79, 87 (1913).

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subsequently find that the trust no longer serves the purposes for which it was created, or that circumstances have so changed that its continuance would be unwise. Thus, California declared "free from the public trust" under the grant to tide and submerged lands in Long Beach, taking one half of the oil revenues and all "dry gas" revenue derived by Long Beach from lands so granted. California did so, stating in the Act of June 6, 1951 that expenditure of more than the sums left remaining subject to the trust "would be economically impracticable, unwise and unnecessary."[48]

The common law rights with respect to ownership of tidelands and submerged lands were designed for and amenable to the needs of commerce, navigation, and the fisheries, and have in the past proved to be adaptable to economic development uses. But new interests have developed in the tidelands and submerged lands. Valuable mineral resources have increased the need for precise boundaries and sound regulatory practices.

New awareness of the biological, recreational, and aesthetic value of marshes, swamps, and tidelands, previously considered waste lands "incapable of ordinary and private occupation, cultivation and improvement," have particularly tested the effectiveness of the common law public trust in which the States have held title to tidelands and submerged lands.

The imaginative interpretation of the common law public trust by State courts, extending the trust to the conservation of natural resources, has been helpful, but only comprehensive planning, legislation, and flexible administrative action have proven effective in managing the increasingly diverse, often conflicting uses in the coastal zone.

E. The Federal Navigation Power

Early in U.S. history the control of navigation was determined to be one enumerated power of the Federal Government under the Commerce Clause of the U.S. Constitution.[49]

The power over navigation is frequently described as a "dominant right," or a "right of a plenary nature," or a "superior power" to which States and private rights have always been "subordinate."[50] Included in the power over navigation is a unique power known as the "navigational servitude," which is an expression for the rule that certain private property rights in navigable waters are subject to a preexisting, continuing right to use such waters and the beds of such waters in aid of navigation,[51] including rights in non-navigable streams which affect navigability of navigable streams, extending to the ordinary high water mark.[52] The right to use navigable waters in aid of navigation is not a right to take title, but a right to use; exercise of the servitude interferes with the enjoyment of riparian rights without impairing their legal status. However, in the exercise of the right, improvements placed in navigable waters by private parties may be removed in exercise of the servitude, without compensation to the owner of the improvement. Such power is unique among the constitutional powers granted to the Federal Government. One explanation is that all private property extending below the ordinary high water mark of navigable streams and coastal waters is placed there with "notice" of the servitude.[53]

A prime example of the exercise of the navigation power is found in the Rivers and Harbors Act of 1899,[54] administered by the Corps of Engineers, which, among other things, governs the building of structures in U.S. navigable waters, and provides for the authorization by permit of dredging and filling in navigable waters.[55]

Federal power over navigation is a great potential asset to the management of certain coastal zone water uses, but one pressing current issue is control of activities, such as dredging and filling, with no adverse effect on navigation, where other values are sought to be preserved.

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[48]See *Mallon* v. *City of Long Beach,* 44 Cal. 2d 199, 282 P.2d 481 (1955); *Twombley* v. *City of Long Beach,* 333 F. 2d 685 (C.A. 9, 1964), *cert. denied,* 379 U.S. 904, *reh. denied,* 379 U.S. 984.

[49]*Gibbons* v. *Ogden,* 22 U.S. (9 Wheat.) 1 (1824).

[50]*United States* v. *Grand River Dam Authority,* 363 U.S. 233 (1960). *United States* v. *Twin City Power Co.,* 350 U.S. 222 (1956).

[51]*United States* v. *Commodore Park, Inc.,* 324 U.S. 386 (1945); *Greenleaf-Johnson Lumber Co.* v. *Garrison,* 237 U.S. 251 (1915); *Lewis Blue Point Oyster Culture Co.* v. *Briggs,* 229 U.S. 82 (1913); *United States* v. *Chandler-Dunbar Water Power Co.,* 229 U.S. 53 (1913).

[52]*Oklahoma ex rel. Phillips* v. *Guy F. Atkinson Co.,* 313 U.S. 508, 525-26 (1941); *United States* v. *Grand River Dam Authority, supra* note 50.

[53]Clark (ed), 2 Waters and Water Rights 16 (1967).

[54]Act of March 3, 1899, 30 Stat. 1151, as amended, 33 U.S.C. 401-416 (1964).

[55]33 U.S.C. 403.

For instance, since 1958, the Fish and Wildlife Coordination Act has required that the Corps of Engineers consult with the Fish and Wildlife Service and with the State administrator of wildlife resources "with a view to the conservation of wildlife resources by preventing loss of and damage to such resources."[56] By administrative agreement between the Secretary of the Interior and the Secretary of the Army, dated July 13, 1967, procedures have been established to review permit applications for dredging or filling. Under the agreement, if the Secretary of the Interior advises that proposed operations will unreasonably impair natural resources or related environment, or reduce water quality below applicable standards, the Secretary of the Army will either deny the permit or impose such conditions as he determines to be in the public interest.

At issue is whether Federal power over navigation includes delegation to the Secretary of the Army of discretionary authority to deny dredging and filling permits where no adverse effect on navigation will result, but health, natural resources, recreation, and other non-navigational values will be impaired.

Additional discussion of this issue is continued in Section II-F, Dredging and Filling. The first tests of the Secretary of the Army's discretionary authority under the River and Harbor Act, with respect to non-navigation values, are pending in the courts.

In addition to the review of Corps of Engineers applications under the Fish & Wildlife Coordination Act, a mechanism is needed to circulate permit applications to all interested Federal agencies for comment, such as in those cases involving construction which might affect the submerged lands limits of the States. Such mechanism might be worked out administratively in the beginning, but we foresee a need for legislative direction from Congress.

F. Submerged Lands

Marshall McLuhan postulates in "Understanding Media" that the introduction of new technology creates a new environment which changes the scale or pace or pattern of human affairs, and shapes and controls the scale and form of human association and action. By necessary implication a new environment creates conflicts and competing uses, and, of course, the need for new order that previously did not exist. The technological capability to exploit oil and gas offshore is an example of a new environment created by technology, which, in turn, has had substantial impact upon the development not only of domestic law but also of international law.

The new environment required definition of ownership and boundaries of the submerged lands surrounding the United States, particularly between the Federal Government and the coastal States, and from the new technological capability has grown major litigation and legislation in the United States, and led to the Geneva Conferences on the Law of the Sea in 1958 and 1960.

The starting point is the principle that both title and dominion, where the tide ebbs and flows, of all the lands below high water mark, are in the sovereign.[57] For a long time it was believed in the United States that each coastal State of the United States was a sovereign, to which title to lands under navigable waters had passed, either by succession to the sovereignty of the Crown as to the original 13 States,[58] or upon their later entry into the Union, as to the Territories.[59] Exploitation of petroleum resources off the coast of California began in 1897, and continued without State or Federal control until 1921, when the California legislature adopted an exploration and leasing act.[60]

From 1921 through 1945, apparently on the assumption that the rules stated above applied equally to *all* lands beneath navigable waters, including those beyond the outer limits of inland waters, California controlled the exploitation of petroleum through leases and permits.[61]

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[56] Act of March 10, 1934, 48 Stat. 401, as amended, 16 U.S.C. 661-666c.

[57] See *Shively* v. *Bowlby*, 152 U.S. 1, 11 (1893). See also cases cited *supra* note 15.

[58] *Martin* v. *Waddell*, 16 Pet. 367 (1842).

[59] *Pollard's Lessee* v. *Hagan*, 3 How. 212 (1845).

[60] Recent discussions of the submerged lands controversies are found in Swarth, "Offshore Submerged Lands," 6 Land and Natural Resources Division Journal 109-57 (April 1968), a publication of the Department of Justice; and Browning, "Some Aspects of State and Federal Jurisdiction in the Marine Environment," a paper presented at the Third Annual Law of the Sea Institute, June 1968.

[61] See Krueger, "State Tidelands Leasing in California," 5 U.C.L.A. L. Rev. 427 (1958).

The long history of States assuming they owned such lands, and Federal acquiescence in such claims, ended in 1947 when the United States Supreme Court decreed that:

The United States of America is now, and has been at all time pertinent hereto, possessed of paramount rights in, and full dominion and power over, the lands, minerals and other things, underlying the Pacific Ocean lying seaward of the ordinary low-water mark on the coast of California and outside of the inland waters [in the marginal sea]... The State of California has no title thereto or property interest therein.[62]

Rationale for the distinction between the title claimed in coastal territorial waters and that claimed in inland waters was explained to be that the contiguity of the territorial seas to the international realm of the high seas makes the subjection and control of such areas significant to matters of defense and foreign relations, which are National, not State, concerns.[63] "The United States here asserts rights in two capacities transcending those of a mere property owner," those of guardian of National safety and of membership in the international community.

United States v. *California* was first in a succession of major cases concerning ownership and boundaries of submerged lands surrounding the United States, and was directly related to the subsequent Submerged Lands Act[64] by which the Congress gave the States title to the bed and natural resources of the territorial sea within their boundaries, with certain limitations and exceptions.

In summary, these cases held: that Louisiana's claims to ownership of the land and resources in the marginal sea within its boundaries were controlled by the California decision;[65] and that when Texas transferred its national sovereignty to the United States, that transfer included ownership of the submerged land of the territorial sea which had been an incident of the sovereignty of the Republic of Texas.[66] Applying the negative implication of the "equal footing" clause in the *Texas* case, the Court said:

The "equal footing" clause prevents extension *of the sovereignty of a State into a domain of political and sovereign power of the United States from which the other States have been excluded, just as it prevents a contraction of sovereignty (*Pollard's Lessee *v.* Hagan, supra*) which would produce inequality among the States.*[67]

Following the *California* case, a Special Master was appointed by the Supreme Court, directing him to answer questions as to principles to be followed in determining two basic issues: (1) identification of the line of ordinary low water, which marks the seaward limit of the State's tidelands, over which the State held title, and (2) identification of the outer limit of inland waters, marking the seaward limit of California's wholly submerged lands, defining seven particularly important or difficult coastal segments.

Although the Special Master submitted his report in 1952, several years passed before the Supreme Court took action on the exceptions to his report, during which the Congress passed the Submerged Lands Act[68] and the Outer Continental Shelf Lands Act,[69] which profoundly affected the course of the California and other States' litigation.

1. The Submerged Lands Act

Basically, the Submerged Lands Act recognizes State ownership of tidelands and lands beneath inland navigable waters, and gives the States title to the lands and natural resources within their boundaries, subject to certain limitations and exceptions. In the operative part releasing and relinquishing all right, title, and interest in such lands and natural resources, the Act deals with (1) title to and ownership of the lands and natural resources, and (2) the right and power to manage and use them, to provide separability of the

[62] *United States* v. *California,* 332 U.S. 804 (1947). The opinion in this case is found at 332 U.S. 19 (1947).

[63] 332 U.S. at 35-36.

[64] Act of May 22, 1953, 67 Stat. 29, 43 U.S.C. 1301-1315 (1964).

[65] *United States* v. *Louisiana,* 339 U.S. 699 (1950).

[66] *United States* v. *Texas,* 339 U.S. 699 (1950).

[67] 339 U.S. at 719-720 [emphasis added].

[68] Note 64, *supra.*

[69] Act of August 7, 1953, 67 Stat. 462, 43 U.S.C. 1331-1343.

management rights in case the title to the submerged lands was found to be constitutionally inalienable.

The Act distinguishes among three areas or classes of lands: (1) tidelands; (2) lands beneath inland navigable waters; and (3) lands beneath navigable waters within their boundaries. "Lands beneath navigable waters" are defined as (a) beds of nontidal navigable waters, up to the ordinary high water line; (b) beds of tidal waters from the mean high water line seaward three geographical miles from the coast line (one geographical mile equalled 6080.19781 feet at that time), and beyond that limit to the State boundary if that was farther seaward as approved by Congress or as it existed when the State came into the Union; and (c) all filed-in, made, or reclaimed lands formerly meeting the definitions above. However, the terms "boundaries" and "lands beneath navigable waters" were limited to three miles from the Atlantic or Pacific Coasts or three leagues (nine geographical miles) in the Gulf of Mexico.

The Act did not resolve the base line from which a State claiming a three-mile seaward boundary was to measure that boundary. It provides that the term "coastline" means the line of ordinary low water along the coast in direct contact with the open sea and the line marking the seaward limit of the inland waters, but left to judicial interpretation how that line would be determined.

The United States retains its navigational servitude and the rights in and powers of regulation and control of the lands beneath the navigable waters for purposes of commerce, navigation, National defense, and international affairs.

2. The Outer Continental Shelf Lands Act

Two-and-a-half months after the Submerged Lands Act was passed, the Congress enacted the Outer Continental Shelf Lands Act, which retains full Federal authority over areas seaward of the "lands beneath navigable waters" disposed of by the Submerged Lands Act. The Act specifically preserves the character of the waters over the seabed and sub-soil of this area as high seas, asserts the jurisdiction of the United States over the Outer Continental Shelf and extends the Constitution, laws, and civil and political jurisdiction of the United States to the Outer Continental Shelf and to artificial islands and structures erected on the shelf to exploit or remove resources.

State laws as of the date of enactment of the Act are adopted as Federal law for the shelf opposite each State, but are to be administered by Federal officials and courts, and are not the basis for a State claiming any interest or jurisdiction over the Outer Continental Shelf.

The adoption of State laws as they existed when the Act was passed gives a static quality to the Act that may prove nettlesome as State laws develop in the future, and require amendment to the basic Act.

Fearing that a claim of territorial sovereignty over the Outer Continental Shelf would be misunderstood and lead other nations to claim sovereignty not only over the shelf but over the superjacent waters, the United States has not asserted "sovereignty" over the shelf, but only claims that the shelf "appertains to" it and is subject to its jurisdiction, control, and power of disposition.

3. The Second Louisiana Case

While the Submerged Lands Act clarified some issues in previous litigation, wide disagreement remained between the United States and certain States as to what had been granted to those States by the Submerged Lands Act. Shortly after enactment, the Submerged Lands Act was declared constitutional, under the absolute power of Congress to dispose of Federal property under Article IV, Section 3, Clause 2, of the Constitution.[70]

In the second *Louisiana* case the Supreme Court sustained the U.S. argument that the Submerged Lands Act did not make an outright grant of three leagues to any State, but rather granted nothing beyond three miles except where a Gulf State could establish that its boundary was more than three miles from the coast when it joined the Union, or as approved by Congress before May 22, 1953. The court held that boundaries in the sea, unlike land boundaries, may be in different places for different purposes, and concluded that for *domestic* purposes a State could have a boundary farther seaward than its boundary for *international*

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[70] *Alabama* v. *Texas, Rhode Island* v. *Louisiana,* 347 U.S. 272 (1954).

purposes, and that a State's rights under the Submerged Lands Act were determined by its domestic rather than by its international boundary.

It then considered the historic claims of the Gulf States to individual domestic boundaries beyond the international boundary of the United States.

With respect to the historic claim of Texas, the court held that Texas entered the Union with a boundary for domestic purposes three leagues from the coast, which was entitled to recognition under the Submerged Lands Act.[71] The court rejected the contentions of Louisiana, Mississippi, and Alabama that they were entitled to a maritime belt of three leagues beyond the outermost islands, and held that their boundaries were three miles from the coast, with the islands to be treated separately.[72]

Florida had claimed that upon readmission into the Union after the Civil War, Congress had approved a provision of its new constitution describing a boundary three leagues from land in the Gulf of Mexico, accepted by the Congress on Florida's ratification of the 14th Amendment. The Supreme Court held that this constituted congressional approval of the three league boundary, entitling Florida to the extended grant under the Submerged Lands Act as to its Gulf Coast.[73]

4. Convention on the Territorial Sea and the Contiguous Zone

Chronologically the next most important event affecting United States seaward boundaries was the Geneva Conference on the Law of the Sea, held in 1958, which led to four Conventions that have now been ratified by the United States. Of them, the Convention on the Territorial Sea and the Contiguous Zone[74] codified the rules for determining the baseline of the territorial sea. The *baseline* is essentially the low-water line as shown on official charts, and closing lines across the mouths of rivers and bays.

The Convention defines *bays* as well marked indentations in the coast line whose area, as a minimum, must equal the area of a semicircle having a diameter equal to the closing line across

[71] *United States* v. *Texas,* 363 U.S. 1 (1960).

[72] *United States* v. *Louisiana,* 363 U.S. 1 (1960).

[73] *United States* v. *Florida,* 363 U.S. 121 (1960).

[74] 15 U.S.T. (Part 2) 1606.

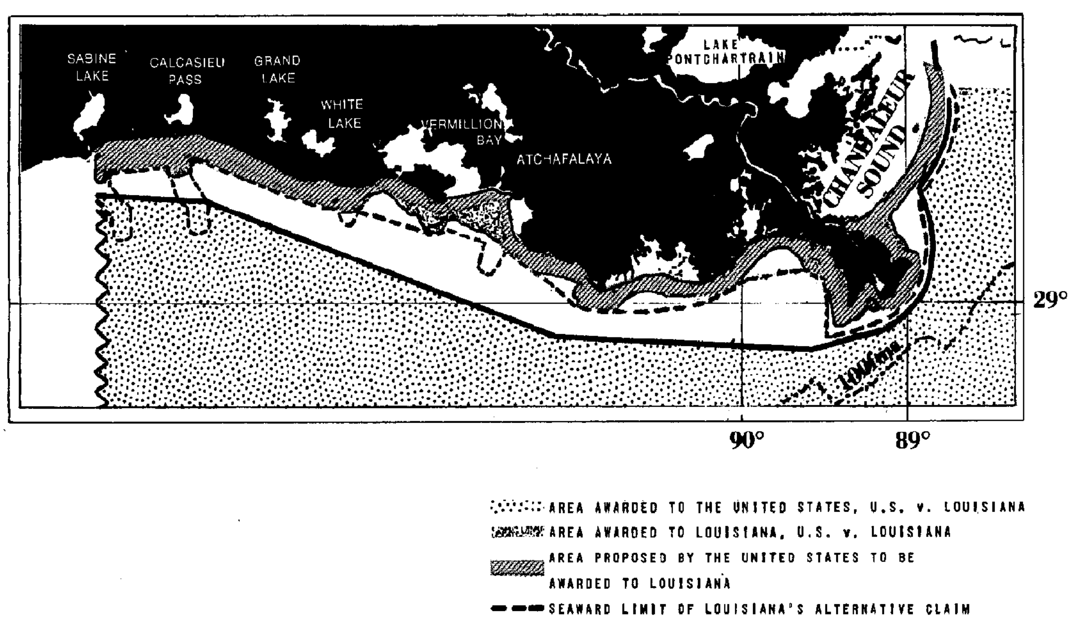

Figure 4. *Louisiana offshore areas awarded or claimed under the Submerged Lands Act. (Source: U.S. Department of Justice)*

the mouth of the bay, or the sum of such lines if there is more than one mouth. If the mouth of the bay is over 24 miles wide, the closing line is drawn within the bay so as to enclose the greatest possible amount of water with a line not over 24 miles long. *Historic bays* are not subject to these criteria.

The Convention also prescribes a method of determining baseline for the coasts of countries fringed with islands, or deeply idented, called the "straight baselines" method. The Convention defines *islands, low tide elevations,* criteria for determining boundaries from the *outermost permanent harbor works* of a coastal country, and provides that the outer limit of the territorial sea is the line every point of which is at a distance from the nearest point of the baseline equal to the breadth of the territorial sea. This is known as the "*arcs of circles*" method of delimiting the territorial sea so that the territorial sea is over all the area within the specified distance of any part of the baseline.

5. The Second California Case

The most comprehensive, definitive statement to date of the principles to be followed in applying the Submerged Lands Act was handed down by the Supreme Court in May 1965 in the second *California* case.[75]

In this case the Supreme Court applied the principles of the Convention on the Territorial Sea and the Contiguous Zone in construing the Submerged Lands Act, rejecting the U.S. contention that the meaning of the Submerged Lands Act was fixed on the date of its enactment. However, the court specifically declared that no future changes in legal principles would affect its meaning. Thus, the court applied the 24-mile closing line rule of the Convention with respect to bays; and defined the "low-water line" as the line of mean lower low water, as modified from time to time by any means, natural or artificial.

While the United States had feared that a State might extend its seaward boundaries by creation of artificial changes in its coast, the court pointed out that the United States could protect itself against such changes by its power to control such activities.

California had claimed that the "straight baselines" method should be applied in determining the baseline in inland waters for its offshore islands. However, the court rejected this claim on the ground that straight baselines can be established only by the National Government. The court also followed the Convention in treating the outermost harbor works forming an integral part of the harbor system as part of the coast from which to measure, and the waters enclosed by them as inland waters.

Thereafter, in December 1965, the court entered a supplemental decree in the *Louisiana* case which, among other things, ordered an accounting by both the United States and Louisiana of the approximately $218,500,000 that had been impounded under an interim agreement in 1956 and derived from areas no longer in dispute. Under the order, about $184,000,000 was released to the United States and about $34,500,000 paid to Louisiana; another $1,100,000,000 has been impounded, awaiting final disposition by the U.S. Supreme Court, and the fund continues to grow.

In February 1967, Texas advertised for mineral leasing certain submerged lands within three leagues of the jetties at Galveston and Sabine Pass, but more than three leagues from the natural shoreline. The United States objected and moved the Supreme Court to enjoin Texas from leasing such lands and to define Texas' rights in the case.

In December 1967, the Court concluded that when the Submerged Lands Act speaks of a boundary "as it existed when the state became a member of the Union" it refers to a completely fixed and immovable line, fixed as of entry of the State into the Union, and excluding consideration of any subsequent changes, either natural or artificial.[76] In so deciding, the court stated that in the 1965 *California* case the court was defining the coastline under the unconditional congressional grant of the three-mile seaward boundary.

In the *Texas* case, the court determined the coastline under the conditional congressional grant based historically on the line existing when Texas entered the Union, and it is apparent that the court will not extend the historical claim.

[75] *United States* v. *California,* 381 U.S. 139 (1965).

[76] *United States* v. *Louisiana,* 389 U.S. 155 (1967).

G. Pending and Prospective Problems

A partial list of pending and prospective problems contained in "Offshore Submerged Lands"[77] is indicative of the activity and economic stake that the United States has in its submerged lands and on the outer Continental Shelf:

–Location of the offshore boundary between Texas and Louisiana–important to the United States because of its effect on the boundary between Texas' three league marginal belt and the Federal submerged lands opposite Louisiana's three-mile marginal belt. *United States* v. *Louisiana.*[78]

–Determination of how the rights and duties of lessees are affected where leases are split by the line finally drawn between Louisiana's submerged lands and those of the United States. *United States* v. *Louisiana.*

–Determination of lands withheld from the States by section 5 of the Submerged Lands Act. *United States* v. *Louisiana.*

–Determination of which of a variety of coastal structures are such "permanent harbor works" as to affect the baseline of California's marginal belt. *United States* v. *California; United States* v. *Louisiana.*

–Specific identification of the entire coast line. *United States* v. *Louisiana; United States* v. *California.*

–Determination whether the Convention on the Continental Shelf has diminished the rights asserted by the United States under the Outer Continental Shelf Lands Act to enjoin a private project to create artificial islands and an independent country on Triumph and Long Reefs, about four miles east of Biscayne Bay, Florida. *United States* v. *Ray,* (Civ. No. 65-271, S.D. Fla.). A second party has intervened in that suit, claiming rights adverse both to Ray and to the United States. *Atlantis Development Corp.* v. *United States,* 379 F. 2d 818 (C.A. 5, 1967).

Off California's southern coast a similar project has been attempted on the Cortes Bank, and may be complicated legally because the Continental Shelf between the Cortes Bank and the mainland is broken by depths greater than 200 meters.

–Sunken treasure, archaeological artifacts, and other wrecked and abandoned property on the Outer Continental Shelf and use of the shelf for purposes other than exploitation of natural resources, raise problems with respect to the authority of the Secretary of the Army to issue permits, and may require legislation or international resolution.

To the list of pending and prospective problems must be added the need for greater boundary stability and new procedures for making binding base line determinations.

At present there are no general procedures by which the Federal Government can enter into agreements with the States on the location of offshore boundaries, except by concurrent legislation or consent decree.

The United States cannot properly initiate a suit unless there is a real controversy, nor should the Supreme Court be asked or expected to exercise its original jurisdiction unless the controversy is of broad general importance. Congress has never consented to being sued by the States in offshore boundary cases, and all such cases must now be initiated by the Federal Government. When the parties agree on a boundary at the outset, neither can properly use court proceedings because there is no true controversy.

As noted earlier, at common law waterline boundaries are ambulatory–as the waterline moves by gradual, natural processes, the boundary moves. Under present principles, when a judgment describes an offshore boundary by metes and bounds, the boundary is stable as long as the coastline remains stable. If erosion moves the line inward, an oil well at the outer edge of a State lease may pass into Federal ownership, extinguishing the rights of the State and its lessee. In the converse situation, the law of the particular State will control ownership of the well.

[77] *Op. cit. supra* note 60.

[78] One commentator reports that of the 18 lateral boundaries between the States, only the line between Florida and Alabama is completely and unambiguously delimited, and the lines of New Hampshire-Massachusetts, California-Oregon, and Oregon-Washington are substantially delimited. In other cases delimiting language is almost completely lacking. See Griffin, "Delimitation of Ocean Space Boundaries Between Adjacent Coastal States of the United States," Third Annual Law of the Sea Institute, June 1968.

Many alternatives are available to solve problems that result from ambulatory boundaries. These include joint Federal-State offshore leasing; or Federal-State recognition of each other's leases, by which each sovereign recognizes leases validly issued by the other, with payments apportioned between the two sovereigns according to the shifting boundary; establishment of fixed boundary lines as of a certain date, using common law principles now in force; or use of straight-line segments.

New procedures are needed for making binding coastal base line determinations. The present procedure for making such determinations by judicial decisions has definite limitations and may be an improvident burden to place upon the Federal courts, especially the Supreme Court.

The panel recommends that a National seashore boundary commission, judicial in nature, be established by the Congress with authority to hear and determine seashore boundary questions and controversies involving proprietary interests of the States under Federal grants to them, using present principles of coastal boundary determination. Such a commission should have the following characteristics and authority:

–The commission should be appointed by the President, with the advice and consent of the Senate.

–The commission should have a limited life, renewable at the option of the Congress.

–The Congress should give its consent to State suit against the United States, permitting States to initiate boundary cases before the commission.

–Jurisdiction of the Commission should be limited to boundary questions between the States and the United States, involving proprietary interests of the States under Federal grants to them. The commission should have authority to determine all aspects of such offshore boundary questions, including those regarding artificial structures and the determination of lateral boundaries between the States, amending 28 U.S.C. 1251(a) which gives the Supreme Court exclusive jurisdiction to hear and determine cases and controversies between the States.

–Authority should be given to file stipulations with the commission, and the commission should be authorized to issue decrees recognizing offshore boundaries, based on stipulations consented to by the State and the Congress.

–When fixed by the commission, coastal boundaries should be defined in terms of geographic or plane coordinates or both.

–Lines determined by the commission or by the Supreme Court of the United States after an appeal would be fixed permanently. Such stabilization should apply only to ownership of submerged lands or resources, not to general political jurisdiction and authority. Authority to regulate mineral lease operations should be stabilized at the property line so determined and fixed.

II. REGULATORY AUTHORITY

Coastal zone regulatory authority must be considered in terms of the two distinct but related regimes of land and water. The law of land-use regulation is highly developed, both as to economic development and preservation of open space and other conservation and recreation interests.

Regulation of underwater lands and their superjacent waters is a much-less-developed area of law, but significant innovations have been made in recent years, including Florida's criteria for locating bulkhead lines and dredging and filling operations; the wetlands protection laws of Maine, New Hampshire, Massachusetts, and Rhode Island; and the State-wide proposals for "Blue Belt" zoning of Hawaii.

These innovations reflect growing concern by various States to develop coastal areas to their highest economic, recreational, and aesthetic potential. As awareness of the value of U.S. coastal and estuarine areas grows, we can expect new approaches to the problems found.

Just as land-use regulation has developed to an imaginative sophisticated art, so also must regulation of water use. Conservation and development are inseparable parts of the same planning and regulatory challenge facing our States and localities. The remainder of this chapter is devoted to regulatory authority for land and water uses as one approach to flexible management of the coastal zone.

A. Land Acquisition and Open Space Preservation

Land acquisition for parks and recreation is well known, and many States and communities are acquiring lands, marshes, streams, and wildlife areas for conservation, watershed protection, flood prevention, and for shaping urban development. Most public acquisition is of the fee title, the surest method of preserving land and other areas for conservation and other public purposes.

Broad powers of land acquisition exist in most States, but the power to acquire property interests less than the fee title is used less frequently than fee acquisition. The majority of States with large acquisition programs still rely on voluntary acquisition, purchase by private conservation groups and municipalities, gifts, and sometimes designation of Federal wildlife refuges.

However, condemnation powers to purchase open space are available in Connecticut,[79] New York,[80] New Jersey,[81] North Carolina,[82] Minnesota,[83] Virginia,[84] Wisconsin,[85] and Maryland,[86] and legislation permitting condemnation to purchase wetlands has been enacted in Connecticut,[87] Massachusetts,[88] New York,[89] and North Carolina.[90]

In some cases variations on the powers of eminent domain exist, such as advance acquisition, or "land banking," a technique used for schools, parks, and airports, to a limited extent where it is established that there is a reasonable necessity for the facility within a reasonable time.[91]

Condemnation of land in excess of that needed for actual development of a major facility may be constitutionally available in some States to control filling, or environmental protection next to highways or transit lines, or to conserve and preserve open space surrounding parks.

Acquisition of the fee title to land and other areas is time-consuming and expensive, and the variations on eminent domain suggested above, or techniques for gradual acquisition of fee owner-

[79] Pub. Act No. 490, §6 (1963).

[80] Conservation Law, §880.

[81] N.J.S.A. 13:8A-1-18.

[82] N.C.S.B. No. 494.

[83] M.S.A. 398.32.

[84] Code of Va. Ann., §10-21.

[85] W.S.A. 32.02; W.S.A. 990.02 (35).

[86] 66C Ann. Code of Md. 357a.

[87] Pub. Act No. 536, §3 (1967).

[88] M.G.L.A., ch. 130, §27a (1967 Supp.).

[89] Conservation Law, §880.

[90] N.C.G.S. 113-226.

[91] See *Board of Education* v. *Baczewski,* 340 Mich. 265, 65 N.W. 2d 810; *Hawthorne* v. *Pebbles,* 166 Cal. App. 2d 758, 333 P. 2d 442 (1959); *Carlor Co.* v. *Miami, Fla.,* 62 So. 2d 897 (1953), *cert. denied,* 346 U.S. 821 (1953). An excellent discussion of these and other methods of acquisition is contained in the San Francisco Bay Conservation and Development Commission report on *Powers,* Vol. 5, "Public Acquisition & Taxation," by Paul H. Sedway and Mrs. Roselyn B. Rosenfeld. For a study of successful open space programs throughout the United States, see "Open Space for Urban America," Department of Housing and Urban Development (1965), prepared by Ann Louise Strong for the Urban Renewal Administration.

Figure 5. *Storm damage of Virginia Beach indicates there may be inadequate controls in the protection and development of coast lands.*

ship[92] or for acquisition of less than fee interests, are made in response both to a desire to plan and implement programs to develop or conserve land or coastal areas and to minimize the initial or long-term public costs.

The San Francisco Bay Conservation and Development Commission suggests possible goals that could be implemented by acquisition: (1) control of size, location, and extent of filling, (2) location and design of facilities and land uses, and (3) designation of permanent open space areas and reservations for future water related uses.[93]

The methods allow varying degrees of public control of the use of property, and, in some cases, permit public recovery of some of the increase in property value resulting from public actions or expenditures. They also offer varying degrees of minimization of public costs, and a choice may have to be made whether to minimize *initial* costs or *total* costs, because measures to minimize initial cost may raise the total final cost of land purchases.

The best way for the public to minimize the cost of buying land is to buy it as soon as possible; no matter how much the price of a parcel has risen during past years, it seems certain that it will rise more in the years to come. This is a problem in every community in the country, but is more acute in a state with a rapidly growing population. . .[94]

B. Land-Use Regulations

Under our Federal system of government, the States possess certain sovereign powers inherent in the nature of the State and not derived from the U.S. Constitution, although restricted by it.[95]

Some incidents of sovereignty included in the State police power are the power to tax,[96] to condemn land,[97] and to regulate land use.[98]

Public safety, public health, morality, peace and quiet, law and order–these are some of the more conspicuous examples of the traditional application of the police power to municipal affairs. Yet they merely illustrate the scope of the power and do not delimit it.[99]

The basic question facing all forms of land-use regulation is to what extent private property can be subject to governmental control. All regulations are subject to the test of "reasonableness," which one leading legal authority has defined in terms of four elements:[100]

–Is the regulation reasonably related to protectible legislative goals? Public health, safety, and welfare, recreation, open space, conservation, and, on rare occasion to date, aesthetic goals have been held to be valid protectible legislative goals to which private property can be subject to regulation.

–Does the regulation provide equal treatment for similarly situated landowners? Particularly relevant is whether comprehensive planning goals exist related as to geography (location of residences, commerce, industry, recreation, open space, agriculture, and other uses of the area to be regulated) and functions (such as being related to communication and transportation). The presence of comprehensive planning may be a major factor in judicial determination of discrimination between similarly situated landowners. Included in the problems of differential treatment of landowners are questions related to denying owners of undeveloped property rights to activities performed by others before the regulation was imposed, and

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[92]Examples of gradual acquisition of fee ownership are (1) options to buy, (2) purchase at request of landowners, (3) installment purchases, (4) purchase and a sale-back or lease-back, and (5) covenants running with the land.

[93]San Francisco Bay Conservation and Development Commission, *Powers,* Vols. 1 and 2 (April 1968).

[94]*Id.*, vol. 5, p. 39.

[95]*House* v. *Mayes,* 219 U.S. 270 (1911); *Cincinnati* v. *Louisville, etc. R.R.*, 223 U.S. 390 (1912); *International Harvester Company* v. *Wisconsin Department of Taxation,* 322 U.S. 435 (1944).

[96]*McCulloch* v. *Maryland,* 4 Wheat. 316 (1816).

[97]*Cincinnati* v. *Louisville, etc. R.R., supra* note 95; *Berman* v. *Parker,* 348 U.S. 26 (1954).

[98]*Munn* v. *Illinois,* 94 U.S. 113 (1876); *Village of Euclid* v. *Ambler Realty Company,* 272 U.S. 365 (1926).

[99]*Berman* v. *Parker,* 348 U.S. 26 (1954).

[100]San Francisco Bay Conservation and Development Commission, *Powers,* vol. 1 (April 1968), by I. Michael Heyman.

differential treatment of owners of presently undeveloped properties.

–To what extent does regulation reduce use and value of the owner's property? The Constitution does not protect property owners against State regulations *merely* because the regulations result in substantial reductions in the value of their property.[101] The States, however, follow many different interpretations, and most are imprecise as to what bases are relevant to measure loss of value or loss of use. Most courts rely on tests that solely measure the difference in market value with and without regulation. However, in the recent Massachusetts case of *Commissioner of Natural Resources* v. *S. Volpe & Co.*,[102] which involved issuance of a permit to dredge and fill wetlands for a marina, the Massachusetts Supreme Judicial Court suggested that many factors, including the owner's investment, fair market value with and without regulation, and "whether a 'taking' would occur if with the restrictions the property would not yield a fair return on the amount of the owner's investment in the property or the fair market value of the property without the restrictions," were relevant to the determination of value and use loss.

–Does the regulation produce a "benefit" for the public which ordinarily would be acquired by condemnation? Illustrative of this concern are recent cases in New Jersey[103] and Connecticut[104] in which land had been zoned for open space and for a flood water detention basin and had created a flood plain district *(Morris County Land Improvement Co.* case), reducing the market value prior to governmental purchase as much as 75 per cent *(Dooley* case). The New Jersey Supreme Court held that the regulation constituted a taking:

Both public uses are necessarily so all-encompassing as practically to prevent the exercise by a private owner of any worthwhile rights or benefits in the land. So public acquisition rather than regulation is required.

The Connecticut Supreme Court of Errors held to similar effect, stating that the plaintiffs had been "deprived by the change of zone of any worthwhile rights or benefits in their land."

The effect of the constitutional provisions requiring "just compensation" for "taking" property is to allocate or spread the cost of a public benefit over the tax base or community rather than have the individual land owner absorb the cost. Many attempts are being made within the United States to seek tests that provide for rational and ethical distribution of social costs, i.e., seeking criteria and methods for measuring the harm or benefit or both resulting from regulation of use.

However, there is no unanimity of approach, and it is impossible to state how each State will balance the equities. Because of the diversity of factual situations, it is doubtful that any State will adopt or limit itself to one test of reasonableness, whether harm-benefit, reasonable reduction in value, or value reduction based on the owner's investment, or some other combination.

It is a truism of the growth of our society that economic values have been emphasized to the detriment of recreational, conservation, aesthetic, and psychological values. In the sphere of land-use regulation, when economic and noneconomic values have come into conflict, the economic value has most often been paramount; cost-benefit analysis is not a very good quantitative technique for handling recreational, ecological, or other qualitative values. Bending to economic pressures has a profound impact on effectiveness of land-use regulatory techniques.

Land-use regulations can provide both incentives or disincentives, depending upon goals sought. Such regulations can be used effectively to encourage economic development. A more difficult problem is in the qualitative sphere, such as the preservation of open space, particularly in light of the presently overwhelming use in the United States of regulation without compensation. In recommending that the role of zoning for open space preservation be restudied and revised, Ann Louise Strong stated in "Open Space for Urban America":

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[101] See, e.g., *Goldblatt* v. *Town of Hempstead,* 369 U.S. 590 (1962).

[102] 349 Mass. 104, 206 N.E. 2d 666 (1965).

[103] *Morris County Land Improvement Co.* v. *Township of Parsippany-Troy Hills,* 40 N.J. 539, 193 A. 2d 233 (1963).

[104] *Dooley* v. *Town Plan and Zoning Comm. of the Town of Fairfield,* 154 Conn. 470, 197 A. 2d 770 (1964).

Traditional zoning has proved ineffective in maintaining open space when pressures of development rise; in addition, it is frequently subject to attack on constitutional grounds when it causes a substantial drop in the market value of land. Zoning should be restricted to cases where (1) no severe loss of land value will occur as a result of the zoning, or (2) where use of the land will pose a serious threat to health and safety of users.[105]

Of techniques available, uncompensated regulation of land use might be considered at one end of the spectrum, and direct acquisition of the fee simple title at the other. As has been pointed out by many, and most recently by the San Francisco Bay Conservation and Development Commission, land-use controls that combine elements of regulation and purchase, such as the compensable regulation technique suggested by Mrs. Strong and elaborated upon by Professors Krasnowiecki and Paul, or the purchase of easements, or the levying of development charges, should be experimented with and used more extensively, for these techniques are intermediate controls between the ends of the spectrum, and offer much promise for the future in the totality of management techniques.

If traditional zoning and other forms of land-use regulation have proven ineffective, it is for reasons other than unavailability of techniques; there is no lack of regulatory techniques or imagination to create new alternatives. Still other land-use regulation techniques should be considered.

To illustrate the need, concepts of water-use regulation, particularly water pollution control, have shown awareness of the concept of "range," which results from currents, the mobility of marine organisms, and other natural factors; the marine environment is not a static environment.

Expressed in legal and management terms, "range" implies regionalization in many coast areas, for the range usually is greater than the geographic limits of any one community, and the actions of one community may have a profound effect upon neighboring communities. This would require change of much land-use regulation jurisdiction in the United States, since such regulation is normally administered at the level of local government.

[105] *Op. cit. supra* note 91, at ix.

One criterion, then, for judging the effectiveness of land-use regulation in the U.S. coastal and estuarine zone will be whether the regulation is effective over the full geographic range in which problems of pollution, waste management and disposal, erection of wharves, piers, or other structures in the water, dredging and filling operations, open space, wilderness preserves for scientific research, or other areas of interest are found.

Further experimentation should be undertaken with new techniques of land-use regulation that take advantage of new information that may help in the decisions to be made. For instance, ecological information is required before the issuance of permits under some of the new wetlands protection laws. As the results of economic, psychological, and health research become available as to the quality, quantity, and proper use of open space in urban and other areas, experimentation with its use in management of the coastal and estuarine zone should be attempted.

Other agencies and reports have made surveys and discussed the advantages and disadvantages of various land-use regulation techniques in greater detail than is possible here. Such a listing of land-use regulation techniques includes:

–Open space zoning
  1. Natural resource zoning
     a. Flood plain zoning
     b. Conservation zoning
     c. Agricultural zoning
     d. Forest zoning
  2. Development zoning
     a. Large lot zoning
     b. Density or cluster zoning
     c. Large-scale development zoning
     d. Zoning for timed development

–Subdivision control

–Official mapping

–Administrative permits

–Legislative permits

–Conditions imposed on granting of development permission

–Techniques combining regulation and purchase

–State-wide zoning.

Some techniques appear to be amenable to the criteria we have mentioned, and are briefly described below.

1. Flood Plain Zoning

Flood plain zoning restricts use of land subject to flooding, which arbitrarily may be determined as a given distance on each side of the center line of a stream, or by mapping actual areas that have been flooded, or by mapping alluvial soils from a soil survey. Some restrictions place limitations on buildings that would constrict stream flow in time of flood, or limit structures to those that would not be damaged by flooding.

2. Administrative Permits

Under this technique, approval or denial of a mandatory permit could be made by members of whatever regulatory agency is empowered to make regulatory decisions, or by staff administrators, subject to appeal to the members or other higher authority of the regulatory agency, and also subject to judicial review.

Administration of this technique can be rigid or flexible depending on powers granted by the legislature. Where the technique has been used on a case-by-case basis for large-scale developments, Professor Heyman reports that its benefits are (1) maximum flexibility, (2) it minimizes differential value impacts which are caused by regulations such as zoning, (3) it can be administered by a professional staff, and (4) it permits finer, more detailed regulation than can be achieved with traditional zoning.[106] Some current examples of administrative permit devices are variances, conditional use permits, special exceptions, and subdivision authorizations.

3. Legislative Permits

This form is similar to the administrative permit, except that the approach reserves power to rule on applications for development permission in the first instance, in the legislative or regulatory body, rather than on appeal of rulings from a regulatory agency administrative or professional staff. Two methods presently used for this purpose are "floating zoning" and "contract zoning."

[106]Heyman, *op. cit. supra* note 100.

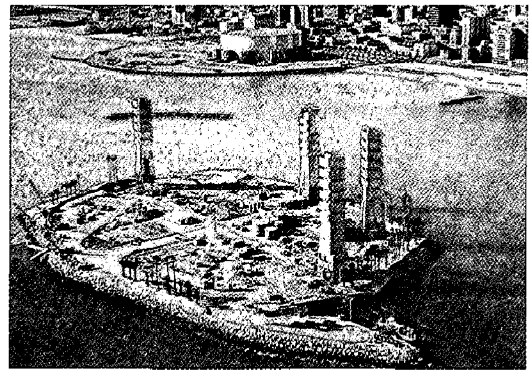


Figure 6. *Oil well construction off Long Beach is now closely regulated. (Long Beach Port Authority photo)*

–A *"floating zone"* is an unmapped district with stated regulations. The ordinance states that applications to remap a zone will be granted if standards contained in the regulations are met. The ordinance also outlines in general when a rezoning application will be granted or not, and the requirements imposed.

–*"Contract zoning"* is the creation and mapping by amendment of a zone with highly detailed regulations different from those of other zones. The amendment is fashioned after negotiations with a prospective developer and reflects the agreement reached between him and the government. Action of the legislature is necessary because the agreement then becomes part of the zoning regulation.

4. Techniques Combining Regulation and Purchase

Compensable regulation is relatively new and untried, combining acquisition and regulation techniques under which land to be retained in undeveloped condition would be mapped and uses established. Under this technique, property owners would be guaranteed that, whenever they choose to sell their land in the open market, they would receive a price at least equal to the value of the land before regulation. If the sale price were less than the guaranteed compensation, the regional agency would pay the difference. The amount of the owners' guarantee for each property reduced by each payment of compensation would remain attached to the property as a guarantee for later purchasers.[107]

[107]For discussion and proposed legislation, see Krasnowiecki and Paul, "The Preservation of Open Space in Metropolitan Areas," 110 U. Pa. L. Rev. 179.

Development charges are fees or taxes imposed on an owner by Government as a condition for permitting the owner to develop his land, or as a tax on the privilege. Measurement of the charge might take one of two forms with respect to coastal land: *a value increase charge* measured by some portion of the difference of value in the land before and after the permit issuance; or a *fill fee* measured by some amount per acre filled or per cubic yard of fill placed in a water area. As suggested by the San Francisco Bay Conservation and Development Commission, the money received from such charges might be used to purchase areas that should never be filled because of special importance, such as wildlife habitats, to buy areas behind existing dikes, or to open up areas to the coastal waters and to improve ecological conditions in some areas, such as by creating new marshlands.[108]

5. State-Wide Land-Use Zoning or Regulations

Traditionally, local governments exercise authority to regulate land uses in the United States. There has been little use of the *States'* power to regulate land uses such as to preserve open space, but as pointed out by the Department of Housing and Urban Development,[109] indications exist of growing interest in the use of State regulatory powers.

Generally, this use for open space has been limited to land use adjacent to highways. Connecticut has adopted State-wide zoning regulations of flood plains. The Wisconsin "shoreland zoning regulation" sets standards for county zoning of unincorporated areas to prevent and control water pollution, protect aquatic life, and preserve natural beauty. The State must adopt its own ordinance in any counties that fail to meet the minimum State standards.[110] Only Hawaii has legislation requiring the State to adopt State-wide zoning.

[108] The Institute of Government, University of North Carolina, reports one instance of a private owner expressing willingness to create a spoil bank, grading it to proper elevation, and planting local marsh grass, to provide more marsh than would be destroyed in dredging a small navigation channel along the shore in front of his property. See Heath, "State Programs for Estuarine Area Conservation," Report to the North Carolina Estuarine Study Committee, April 1968.

[109] Department of Housing and Urban Development, "Open Space for Urban America," 1965.

[110] Wisc. Stats., §§59.971, 144.26 (Supp., Vol. 3, 1965).

C. Establishment of Bulkhead Lines

Although the Corps of Engineers is empowered to regulate dredging and filling for any improvement to navigable waters, the States and local governments may require permits for such work in addition to those issued by the Corps under the Rivers and Harbors Act of 1899.[111]

One regulatory technique upheld by some State courts has been the establishment of bulkhead lines, by which the States regulate filling and reclamation of privately owned tidelands,[112] particularly where the filling might interfere with navigation. Florida has made a series of amendments to its criteria for dredging and filling permits,[113] and now requires that, before a bulkhead line is located, local authorities must first obtain a biological survey, ecological study, and, if deemed necessary, a hydrographic survey from the State Board of Conservation. The Board has issued a circular containing guides for evaluating marine productivity and adopting standards for waterfront development. Until such studies are completed, the Trustees of the Internal Trust Fund, who administer the statute, have placed a State-wide moratorium on dredging and filling. Recommended removal of the moratorium in nine counties has been the subject of recent controversy within the State.

Florida once actively encouraged reclamation of tidelands by private interests, but now has elaborate conservation criteria written into its statutes. Among the considerations: potential interference with riparian rights; impediment to navigation, interference with conservation of natural resources, with findings as to potential harm to specific types of marine life or marine habitat. Dredging beyond bulkhead lines is only to be permitted for navigation channels, installation of utilities, shore protection work, or after conclusive determination that the dredging or filling will not harm marine life, marine habitat, or natural shoreline processes. This last requirement has yet to be defined by the courts.

[111] See *Cummings* v. *Illinois,* 188 U.S. 410, 431 (1902).

[112] See, e.g., *Gies* v. *Fischer,* 146 So. 2d 361, 362 (1962).

[113] Florida Laws 1963, ch. 63-512; Laws 1967, ch. 67-393, §§2-9 (Fla. Stats. Ann., §§253.122-135, Supp. 1968).

Such other States as Texas,[114] Virginia,[115] and Alabama[116] regulate such limited uses as the leasing of submerged lands or protection of shellfisheries, through the establishment of "bulkhead lines" or "harbor lines."

D. Wetlands Protection Laws

Closely akin to the Florida approach regarding bulkhead lines are the statutes enacted in several States which are designed to protect and conserve ecological values. These States include Maine,[117] New Hampshire,[118] Massachusetts,[119] and Rhode Island.[120]

The Massachusetts statute prohibits the removal, filling, or dredging of any bank, flat, marsh, meadow, or swamp bordering on coastal waters without a permit from the State Commissioner of Natural Resources, and specified local governing bodies. In addition, a related statute authorizes the Commissioner, with approval of the Board of Natural Resources, to adopt regulations concerning alteration or pollution of coastal wetlands. If the State courts find the regulations constitute a "taking" of property in violation of the 5th Amendment of the U.S. Constitution, the Department of Natural Resources may condemn the land in fee or lesser interest by eminent domain.

Other States, while having no express wetlands protection laws *per se,* require considerations other than navigation in granting permits and leases. New York requires its Commission of Conservation to ascertain the probable effect on the use of navigable waters for navigation, the health, safety, and welfare of the people, and the effect on the natural resources of the State, likely to result from channel excavation or fill.[121] Oregon's criteria for granting a lease to remove material for commercial use include considerations of health, safety, and welfare; interference with residential or recreational areas; interference with aesthetic or scenic value; creation of air, water or other pollution; danger to marine life or other wildlife; as well as interference with commerce or navigation.[122]

E. Regulation of Wharves, Piers, and Other Structures[123]

While in English common law the upland owner had no right to wharf out into the

[114] Texas Stat., art. 5415e(7).

[115] Va. Code, §62-2.1 (1966 Supp.).

[116] Ala. Stats., tit. 38, §122.

[117] 12 Maine Rev. Stat. Ann., §4701 (Supp. 1967).

[118] N.H. Rev. Stat. Ann., ch. 483-A (Supp. 1967).

[119] Mass. Gen. Laws. Ann., ch. 130, §27A (1967 Supp.).

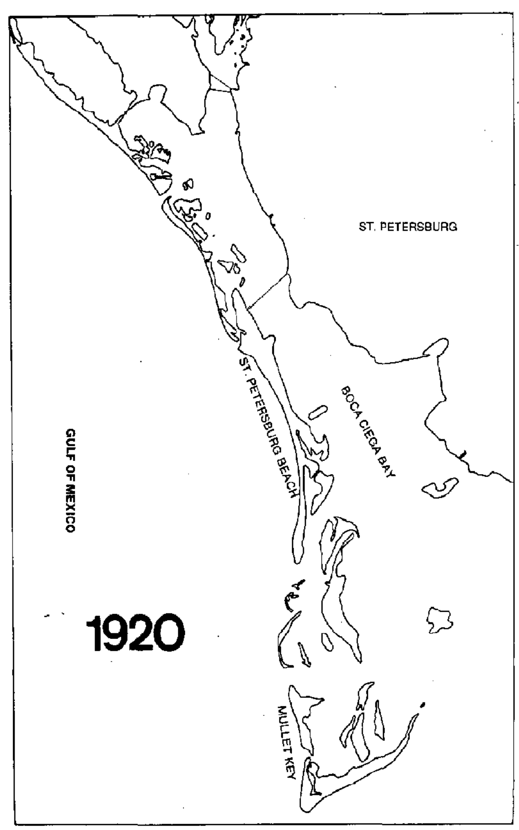
[120] Rhode Island Gen. Laws, tit. 46, ch. 11, §1-1 (1967 Supp.).

[121] New York, Conservation Law, §429(b)(3).

[122] O.R.S. 274.760.

[123] We wish to acknowledge the work of the Marine Environment Legal Research Project of the New York University Law Center and Fordham University School of Law. Their paper, "The Land-Sea Interface of the Coastal Zone of the United States: Legal Problems Arising Out of the Multiple Use and Conflicts of Private and Public Rights and Interests," under a contract let by the National Council on Marine Resources and Engineering Development, and their advice have been of considerable assistance in the preparation of sections E and F, as well as certain other parts of this chapter.

Figure 7. *Progressive dredging and filling in Boca Ciega Bay, St. Petersburg, Florida, 1920-1965. Present jurisdiction to control excessive development is being contended. (Source: Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg, Florida)*



tidelands without a permit, early decisions in the United States encouraged the erection of wharves for the benefit of navigation and commerce. At present a majority of the coastal States allow the adjacent owner to wharf out in most cases without a permit, either as a part of the State's common law or by statute.[124]

However, probably no State now does not exert some form of control over the construction of wharves, piers, and other structures, even in those States that still adhere to the rights of the riparian owner to wharf out over tidelands. In some States, control over construction of wharves, piers, and other structures is exerted by the State, in detailed legislation,[125] or by delegation to a State agency,[126] or by delegation to a local agency.[127]

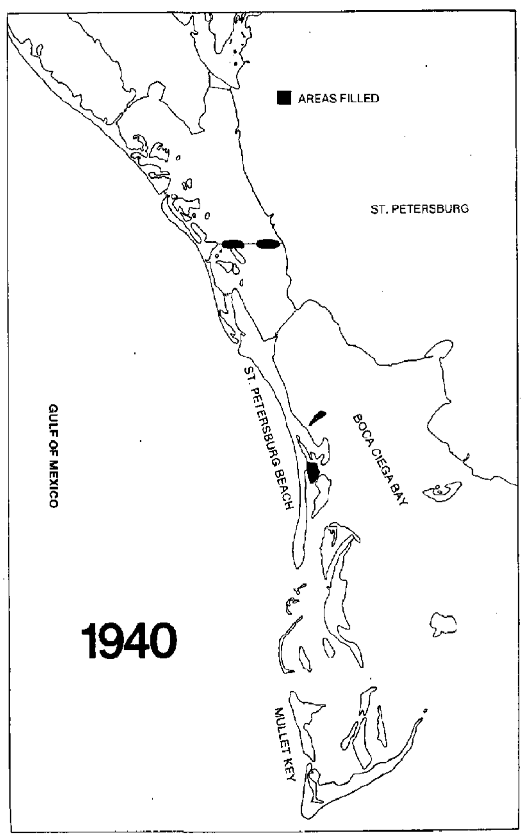
Municipalities are normally granted powers by the State to regulate the construction of wharves

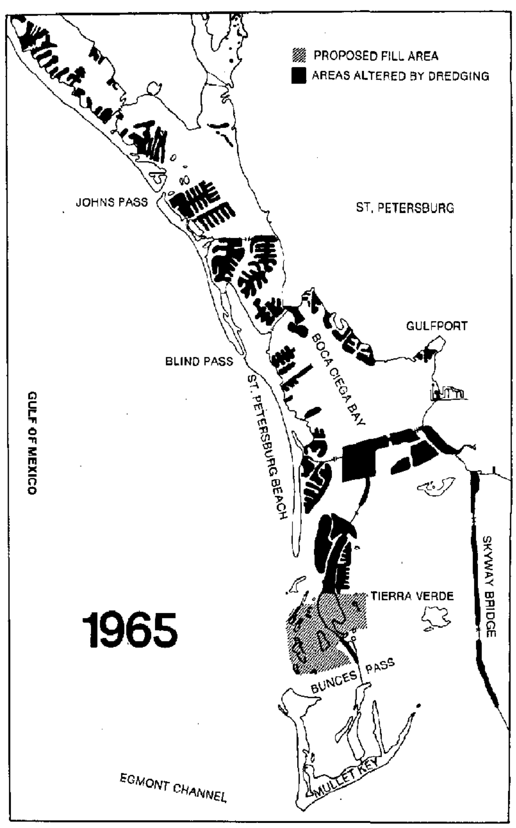
[124] *Washington:* R.C.W.A., §88.24.010. See *Eisenbach* v. *Hatfield,* 2 Wash. 236, 256 Pac. 539, 542-43 (1891). *Oregon:* O.R.S., ch. 780.040. *Mississippi:* Miss. Code Ann., §6047-10. See *Harrison County* v. *Guice,* 244 Miss. 95, 140 So. 2d. 838, 842 (1962). *Alabama:* Ala. Stats. 38, §119. *Virginia:* See *U.S.* v. *Smoot Sand and Gravel Corp.,* 248 F. 2d 822, 826 (4th Cir., 1957). *Maryland:* Md. Ann. Code, art. 54, §46. *Pennsylvania:* 55 Penna. Stat. Ann., §8. *Connecticut:* See *Miances Realty Co.* v. *Greenway,* 151 Conn. Rep. 128, 193 A. 2d 713, 715 (1963). *Massachusetts:* See *Commissioner* v. *Alger,* 61 Mass. 53, 104 (1853).

[125] New Jersey, N.J.S.A. 12-3-3. Statute contains detailed prescription of intervals between piers and the manner in which works are to be constructed.

[126] *New York:* Conservation Law, §429c–requires permit for wharves, docks, and piers used as landing places, exempting a limited class of structures from the permit requirements. Permits are handled by State Commission of Conservation. Permit review includes values other than navigation, i.e., erosion from banks, injury to fish and aquatic resources, increase of turbidity, deposition of silt or debris. Public hearings may be held. *Rhode Island:* R.I. Gen. Laws, tit. 46, ch. 6, §2. Approval of plans to construct wharves or piers must be obtained from the Department of Natural Resources. *Florida:* Fla. Admin. Code., §200-2.16. Administrative function of executive branch of government to grant permit for piers, wharves, etc. in public navigable waters. See *Sarasota County Anglers Club, Inc.* v. *Burns,* 193 So. 2d 691, 693 (1967). Administrative Code requires open trestles or pilings which do not materially deflect water currents, or induce erosion or accretion.

[127] *California:* Harbor and Navigation Code, §§4000-4009–Boards of supervisors of counties may grant authority to wharf out within county boundaries, and grant authority to wharf out on lands other than those mentioned above.





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and other structures in the waters within their boundaries, and to regulate their use,[128] including regulation by zoning under the police power delegated to the municipalities.[129]

F. Dredging and Filling

Earlier chapters of this Report have discussed the impact of dredging and filling for navigation purposes on the ecology and hydrology of coastal areas. Dredging and filling takes many forms, including mining of sand, gravel, and oyster shells, disposal of spoil, pumping of sand to make beaches, of fill and solid wastes for housing and other real estate developments, draining of marshland for mosquito control, and reclamation of marshland for agriculture.

The range of State attitudes toward protection of coastal and estuarine areas varies considerably. Appendix D to this report presents in summary form some means by which States regulate coastal and estuarine areas. It reports that:

a common denominator of regulation in all or most of the states in participation in Corps of Engineers navigation permit proceedings, general water pollution control laws, fish and game regulations, and some controls exercised in conjunction with disposal or lease of state owned underwater lands.[130]

The enumerated controls also appear to be the minimal powers available to our coastal States. To them must be added the powers that several States have granted, extending authority well beyond those stated, and, indeed, ahead of existing Federal legislation.

In some States, navigation is still the principal criterion for allowing dredging or filling of tidelands.[131] However, the role of the Corps of Engineers, acting either pursuant to the Fish and Wildlife Coordination Act, or on the basis of State or local objections to proposed dredging or filling operations, can have a significant impact upon preservation of non-navigation values.

It is the policy of the Corps of Engineers that in cases where a proposed structure or dredging operation is unobjectionable for the purposes of navigation, but State or local authorities decline their consent to the work, the Corps normally will *not* issue a permit.[132]

The ultimate authority for use of tidelands and submerged lands, with respect to navigation, lies with the Federal Government and its control of navigation under Article 1, section 8 of the U.S. Constitution, the Commerce Clause. Federal control over dredging and filling to improve navigation is implemented by the Rivers and Harbors Act, based on Congress' power over navigation.[133]

While this Act and the cases interpreting give unquestionable authority to the United States to control improvements for navigation, one unsettled question is the degree, if at all, Congress' power over navigation under the Commerce Clause can be extended to preserve other values in the coastal zone. Under the Fish and Wildlife Coordination Act,[134] the Corps of Engineers is required to consult with the Fish and Wildlife Service of the Department of the Interior before granting a dredging or filling permit, a process administratively agreed upon by the Secretaries of the Interior and Army, by their agreement of July 13, 1967.

Both the Fish and Wildlife Coordination Act and the administrative agreement seek to combat pollution and to conserve natural and recreational

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[128] Cf., *New York:* Conservation Law, §429c; *California:* Harbor and Navigation Cases, §3821; *Connecticut:* Statutes, §15-7; *Mississippi* Code Ann., §3374-142; *New Jersey:* S.A., §40:68-12; *South Carolina:* Code, §47-61.1-61.2; *Louisiana:* S.C.C.C., art. 452; *Florida:* Stat. 167.21.

[129] See *Brady* v. *Board of Appeals of Westport,* 348 Mass. 515, 524, 204 N.E. 2d 513 (1965). See also, zoning regulations, Town of Guilford, Conn., §4.5.8-1; City of Richmond, California, Ordinance No. 125 N.S. Examples of special zoning districts for tide and shorelands in California are the City of Chula Vista's Tidelands Zone, established by Ordinance No. 795 (1962); the City of Coronado's Beach Zone, established by Ordinance No. 1147 (1967); or the City of Richmond's Special Features Additive District, established by Ordinance No. 122 N.S. (1965); and in Florida the City of Sarasota's Marine Park District, established by Ordinance No. 1494 (1967). In all of these districts, uses and activities incompatible with the development concept of the whole are either eliminated or severely restricted.

[130] *A Selected Summary of State Activities in Coastal Regulation,* Milton S. Heath, Jr., Institute of Government, University of North Carolina, Chapel Hill, North Carolina, July 1968.

[131] See, e.g. *Alabama:* Ala. Stats., Title 38, §122; *Delaware:* Del. Code Ann., Title 23, §150; *Virginia:* Va. Code, §62-2.1 (1966 Supp.).

[132] Estuarine Hearings, *supra* note 43, at p. 137.

[133] Act of March 3, 1899, 30 Stat. 1151, 33 U.S.C. 403 (1964).

[134] Act of August 12, 1958, 72 Stat. 563, 16 U.S.C. 662 (1964).

resources in dredging and filling U.S. navigable waters.

The first test of Corps of Engineers authority to deny a permit for reasons other than adverse effect upon navigation is pending in the Federal courts. The case of *Zabel* v. *Tabb*[135] places at issue the discretion of the Corps of Engineers to deny a permit for dredging and filling under the Rivers and Harbors Act on grounds other than navigation. The question of Congress's power to give such discretion is not challenged in the case. The Corps found that the work would not have an adverse effect upon navigation, but denied the permit because issuance of the permit (1) would result in a harmful effect on the fish and wildlife resources in Boca Ciega Bay; (2) would be inconsistent with purposes of the Fish and Wildlife Coordination Act of 1958; (3) was opposed by the Florida Board of Conservation, the County Health Board of Pinellas County, and the Board of County Commissioners of Pinellas County, and (4) would be contrary to the public interest.

At this writing the court has denied the motion of the United States to dismiss the case on jurisdictional grounds, and the case has not yet been heard on the merits.

However, in denying the motion to dismiss, the court stated that the Fish and Wildlife Coordination Act does not give discretion to the Corps to deny permits on grounds other than navigation. While it is too early to speculate on the outcome, it is clearly an important case testing the very essence of Federal law attempting to protect natural resources through exercise of the navigation power.

In another pending case, the United States seeks to enjoin a dredging operation in Newfound Harbor, Florida, on objection from the Federal Water Pollution Control Administration and the Florida State Board of Health that the flow of sewage effluent from a nearby sewage treatment plant is being blocked, creating a health hazard. The injunction is sought under the Rivers and Harbors Act of 1899, for failure to obtain a permit for the dredging and filling operations.

[135] *Alfred G. Zabel and David H. Russell* v. *R. H. Tabb, Col., USA, Stanley Resor, Secretary of the Army, and the United States of America*, Civ. No. 67-200-T, United States District Court for the Middle District of Florida, Tampa Division.

G. Summary

The techniques for regulating land uses are numerous, ranging from public acquisition of fee simple title through a variety of forms of compensable regulation, to noncompensated regulation such as classical zoning. The techniques for water-use regulation range from efforts to promote navigation for commercial purposes, through wetlands protection laws which provide for ecological considerations in regulation, to State-wide water-use zoning, such as that proposed in Hawaii.

In making plans and decisions to manage the coastal zone, both land and water uses must be taken into consideration in determining the powers to be granted and the functions to be served by any government agency having the responsibility and jurisdiction to manage the coastal zone.

Economic interests have been well-served by regulatory techniques in the past, and must continue to be strongly represented in future regulation. Historically more difficult in our society is the use of regulatory techniques to serve qualitative values—aesthetics, conservation of natural resources and wildlife, and preservation of open space.

However difficult it is to serve qualitative values, balanced management of our coastal environment requires effective planning, regulation, acquisition, and enforcement, consistently applied, to preserve and enhance both the qualitative values and the economic interests found in the coastal zone.

We have briefly touched upon the legal problems confronting any State or local authority given the responsibility to plan for management of a coastal area. All of these should be considered in granting powers to any governmental agency such as recommended in Chapter 10, i.e., establishment of State authorities or State-established local or regional authorities to manage coastal areas. There we suggest a range of State management authority, including planning, regulatory, and acquisition authority with respect to coastal and lakeshore waters and lands.

Management might be provided by a single State agency, given all the powers suggested as to land and water uses. A second alternative might be a State agency with authority over water uses and shared jurisdiction with local governments as to land uses.

Unless given strong, consistent backing by all local governments involved, regional cooperative efforts under a single advisory agency will not be adequate to meet the needs of effective coastal management, and we do not recommend such efforts. Management powers granted a State, regional, or local authority will depend in large measure on the answers to some legal problems presented in this chapter. The legal problems and the techniques for effective management of the coastal zone are well known. They must be integrated with adequate planning, flexible authority, and sound research, to provide for balanced, diverse coastal zone uses.

The preceding chapters have presented the activities and pressures on the coastal zone. The conflicts have been identified and the consequences discussed. We have seen that man's past actions affecting estuaries and shorelines have been poorly and incompletely planned, often unimaginative, and frequently destructive. In view of the many important uses served by these waters, and the growing pressures on them, intelligent management of this vital National resource is imperative. It will require application of many kinds of tools and techniques, ranging from original, fundamental research to regulatory changes and public education.

A National policy for the management of our coastal environment is urgently needed. This program is presented in Chapter 10.

Based upon the many public contacts, interviews, correspondence, reports, and information available to the panel, we have established what we believe are the "National Needs." They are presented in this chapter under five general headings:

–The Need for Immediate Action

–The Need for Federal Surveys and Projects

–The Need for Research and Training

–The Need for Planning and Management

–The Need for a Systematic Approach to Waste Management

The first two "needs" emerge from the Commission's role to review existing programs. They are not new or long range, but simply need to be done and done soon. The second two "needs" are clearly within the role of the Commission in planning for the future. They contribute to a proposed National program. The last–while of vital importance to the coastal zone–encompasses far more than the marine environment.

I. THE NEED FOR IMMEDIATE ACTION

Pressures are mounting on coastal and estuarine area use to make physical modifications and economic commitments which are virtually irreversible. It is in the National interest, however, to preserve as much as possible the options which are open to us. It is therefore advisable to err on the side of conservation.

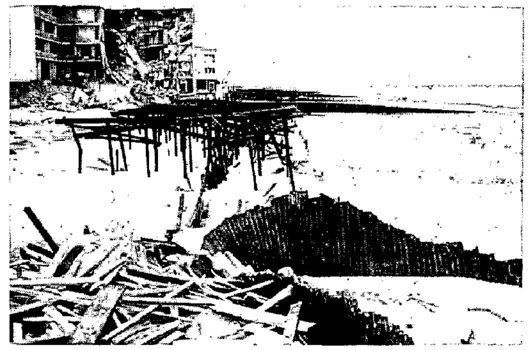

Figure 1. *Storm damage at Rehoboth Beach, Delaware. Federal surveys are needed to assess the use of coastal areas and their protection. (U.S. Army Corps of Engineers photo)*

All available existing legislation, Executive Orders, and regulations should be utilized by the Federal Government and by State and local governments to achieve this aim as rapidly as possible; additional legislation should be adopted where necessary. For example, State governments should strictly enforce their water quality standards for their coastal zone waters; pollution abatement action should be initiated whenever cause exists. States should be encouraged to adopt appropriate tidelands legislation (following model legislation, such as in Massachusetts and New Hampshire[1]). Estuary construction projects requiring permits from the Corps of Engineers should be scrutinized more severely by both State and Federal agencies. Permit requirements should be rigidly enforced. States should be encouraged to consider the feasibility of a total or partial moratorium until an overall plan is developed (as done under California law by the San Francisco Bay Commission[2]). All Federal agencies involved in granting licenses (e.g., AEC, FPC) or in granting planning or construction funds to municipalities or States (FWPCA, HUD, USDA, EDA, and others)

[1] See Chapter 8 and Appendix D.

[2] See Appendix D.

should relate awards on the basis of overall consideration; disposal of Federal surplus coastal lands by the General Services Administration should be suspended until public interests are adequately defined.

Fulfillment of many of these urgent needs can be accomplished by two general means:

–Use of authority which already exists

–Action on pending legislation.

A. Use of Existing Authority

Many coastal zone problems have been identified with pollution, eutrophication, and general public loss of shoreline resources. In many cases, control of these abuses can be exercised–or at least further deterioration retarded–by prompt and vigorous enforcement of existing authority and laws. In many cases, the lack of enforcement is principally due to funds' not keeping pace with burgeoning enforcement responsibilities. In other cases, however, it is due to complacency, tangled jurisdictions, and–as several State and Federal officials have remarked–a plain lack of guts.

Though many laws may be obsolete, ambijurisdictional, or in need of clarity, they can–for contingent purposes–suffice, based on cooperation between both State and Federal Agencies. These include:

–The Federal Water Pollution Control Act, (33 U.S.C. 466 *et seq.*) as amended, is an important Federal tool in the prevention of water pollution. The Act requires the States to establish enforceable water quality standards applicable to interstate waters. These standards must be approved by the Secretary of the Interior, must protect public health and welfare, and enhance water quality. If a State fails to establish acceptable standards, the Secretary of the Interior is empowered to issue such standards. Enforcement of water quality standards is a most effective method of preventing pollution of a continuing nature. However, the time period between notice of a violation and the abatement thereof is unreasonably long in the case of sudden, non-recurring pollution incidents. This situation should be remedied by amending existing legislation and is discussed in greater detail in Chapter 4.

–The Outer Continental Shelf Lands Act (43 U.S.C. 1331-1343) authorizes the Secretary of the Interior to require the prevention of pollution in offshore oil or mining operations. In the implementation of this Act, a requirement for compliance with antipollution regulations could be made a condition of any lease, revocable upon failure to comply. Further, this act specifically authorizes the President to withdraw from disposition any of the unleased lands. Under the terms of this authorization a system of fishery preserves, mineral reservations, sanctuaries, and recreation areas could be established. Safety provisions of this same act, administered by the U.S. Coast Guard, are indirectly a pollution prevention tool. Navigational safety regulations to prevent collisions also prevent pollution.

–Rivers and Harbors Act of 1899 (33 U.S.C. 407), administered by the Corps of Engineers, requires that plans for all wharves, piers, dolphins, booms, weirs, break-waters, bulkheads, jetties, or other structures, and excavations or fills in navigable waters must be approved under a permit system. Although all tidelands and marshes may not come under the provisions of this Act, it allows strong regulatory action over modifications to coastal waters, especially dredging and filling. Constant enforcement is required.

–The Refuse Act of 1899 (33 U.S.C. 407), administered by the Corps of Engineers, applies to both vessels and shore-based facilities with respect to almost every discharge to a navigable water except that flowing from streets and sewers. A 1965 judicial ruling construed the act to include the discharge of oil products as well as solid wastes.

–The Oil Pollution Act, 1924, (33 U.S.C. 431 *et seq.*) makes unlawful, with some exceptions, the grossly negligent or willful discharge of oil from a vessel into the navigable waters and adjoining shorelines of the United States. The prohibition applies to foreign and domestic vessels within our territorial sea and navigable inland waters. The act establishes both civil and criminal sanctions for violations. The exceptions are emergencies imperiling life and property; unavoidable accidents, collisions, or strandings; and those cases where discharges are permitted by regulation. Enforcement of this act is vested in the Federal Water

Pollution Control Administration, Coast Guard, and the Corps of Engineers. Regulations by the Secretary of Interior incident to this law should be issued and vigorous enforcement conducted by responsible agencies. Account should be taken of certain weaknesses in this legislation. To focus effort on prevention of spills, as distinct from cleanup, there is need for explicit Federal authority to issue Federal regulations concerning the ways in which oil is handled and stored. In addition, the Oil Pollution Act does not apply to oil discharges from shore-based facilities. This omission is critically significant. The Corps of Engineers estimates that 40 per cent[3] of all oil pollution enforcement cases in the past grew out of non-waterborne oil discharges.

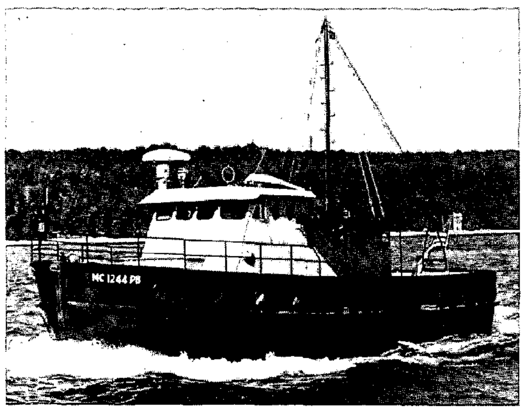

Figure 2. *Research Vessel* Mysis *of the University of Michigan. Coastal research affiliated with academic institutions is needed. (National Science Foundation photo by Herb Reynolds, Sturgeon Bay, Wisconsin)*

–Oil Pollution Act of 1961 (33 U.S.C. 1001) enacts the International Convention of 1954 and provides for enforcement of oil pollution control outside territorial waters. This act, enforced by the Coast Guard, prohibits discharge of oil in offshore zones (50 or 100 miles), requires reporting of spills or losses, and requires participating nations to promote adequate oil receiving facilities in ports. Certain provisions might usefully be reviewed: whether exemptions should continue for certain classes of smaller and older vessels; whether the allowable discharge in a sea-water mixture prevents damaging pollution; and whether, pursuant to the terms of the International Treaty, oil receiving facilities can accommodate current levels of ship traffic.

–Fish and Wildlife Coordination Act (16 U.S.C. 661) requires that whenever the waters of any stream or other body of water are proposed to be diverted, channel deepened or otherwise controlled or modified for any purpose whatever by any Federal agency or private or public agency under Federal permit such agency shall consult with the U.S. Fish and Wildlife Service and with the State agency having administration over wildlife resources which may be affected.

–Executive Order 11288 of July 2, 1966, requires that all Federal agencies comply with the provisions and standards of the Federal Water Pollution Control Act and cooperate with the Department of the Interior and appropriate State agencies in preventing or controlling water pollution. This can be an important tool of the Federal Government in preventing pollution. It is discussed in detail in Chapter 4.

–Executive Order 9634 of Sept. 28, 1945, provides for establishment of fishery conservation zones in areas of the high seas contiguous to the coasts of the United States. This order allows for the establishment of marine wildlife sanctuaries as a fishery conservation measure.

B. Action on Existing Recommendations

There are many existing recommendations by competent bodies and studies which treat the coastal environment. These recommendations stem from the need, often urgent, to correct deficiencies laid bare by such disasters as the *Torrey Canyon* and *Ocean Eagle.* The panel has reviewed the following reports and calls to the attention of the Congress and executive agencies the need for prompt consideration of certain recommendations which are reiterated here:

Effective Use of the Sea, Report of the Panel on Oceanography of the President's Science Advisory Committee June 1966. This report is an important reference for the Commission. Two principal recommendations emerge with respect to the coastal zone.

[3] Oil Pollution: A Special Study by the Secretary of the Interior and the Secretary of Transportation, 1967. This is an excellent report on the subject. It discusses the weaknesses and inadequacies of the oil pollution laws.

out the major recommendation of this report including the assignment of liability to pollution. Both the contingency plan and the proposed legislation appear essentially to fulfill the intended goals. Implementation is urgently required. We concur with the need for and funding of research in this field.

Industry and the Ocean Continental Shelf, A Report by the Ocean Science and Technology Advisory Committee (OSTAC) of the National Security Industrial Association (NSIA), 1967. The second Continental Shelf Conference was convened April 12-14, 1967, under the co-sponsorship of NSIA-OSTAC and the Federal Government. Five basic non-defense industries were represented by petroleum, mining, chemical, fishing, and recreation industry leaders; Government agencies were represented by their counterparts.

The goal of the conference was to enumerate and recommend solutions for those problems whose solution would encourage a more rapid growth of each industry's oceanic activities: specifically, problems that could be solved by a closer working relationship between industry and the Federal Government and problems which are "manageable" and "attainable" within five years.

Recommendations resulting from that conference include the following to which this panel also subscribes:

–*Prediction and control of the environment.* Storms and storm waves affect all users of the sea, including recreation, and occasionally inflict heavy damages to property and cause loss in harbors, not only from their direct effects but also from erosion and the shifting of sediments which alter shorelines and fill channels. In view of this, the following recommendations are made:

> Efforts to predict and control hurricanes should be intensified.
>
> A shallow water forecasting capability should be developed, especially for the Gulf of Mexico, where it is of paramount importance.
>
> Industry has offered its offshore platforms and ships as real time measurement stations, rent-free. Pertinent Government agencies should be encouraged to use these platforms.
>
> A National marine environmental reporting and forecasting service should be established. Existing organizations, such as the U.S. Navy Fleet Numerical Weather Facility, Coast Guard, Bureau of Commercial Fisheries, U.S. Oceanographic Office, and ESSA, should support this service. Computer facilities and radio stations and frequencies should be pooled for use in such a National network.[15]

–*Multiple use conflicts and traffic control.* The growth of industry, population, and recreational activity in estuarine and inshore waters can be expected to accelerate and bring increasing problems of conflict.

> Development of maritime traffic control methods for congested waters should be accelerated. The present extremely hazardous practice of allowing vessels to pick their own way results in undue risk of life and property.[16]
>
> The Department of the Interior should study the feasibility of making available additional seacoast and Great Lake areas for recreational use, possibly including private lands with owner concurrence.
>
> It is suggested that all multiple uses of an area determine a method for establishing a realistic dollar value, in addition to other pertinent factors, to their various interests. Without this dollar value logical and rational decisions regarding the optimal use of waterfront areas cannot be made.
>
> For maximum recreational use of coastal waters pertinent Government agencies should be encouraged to expand search and rescue coverage, to establish additional harbors of refuge, and to study navigation aids with specific regard to their recreational assistance.

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[15] For a detailed discussion on these recommendations the reader's attention is directed to the Panel Report on Environmental Monitoring and Prediction.

[16] See Section XI of Chapter 2.

–*Legal/Regulatory Considerations.* The Federal Government should:

Enact legislation capable of serving as a model to encourage uniformity in Federal-State laws and regulations. Uniformly interpret existing Federal laws and regulations.

Under the recently enacted legislation establishing a 12-mile fishing zone, neither Federal nor State governments have clear responsibility to conserve fishing resources. Accordingly, it is recommended that the Secretary of Interior take steps to cooperate with the States and with existing regional fishing commissions in any regulations required to develop fisheries between the 3-and 12-mile limit.

–*Surveys.* Well planned hydrographic and geological surveys of the U.S. Continental Shelves are the backbone of Federal, State, and industrial planning. As such they do much to encourage the rational and orderly development of the Continental Shelf. However, surveys which do not take into account the various user data requirements and which are conducted without the use of modern data collection and processing techniques are wasteful. Specifically, the Federal Government should:

Generate maps of bottom topography of the U.S. Continental Shelf overprinted with gravimetric, magnetic, bottom type, and other geological information.

Accuracy in surveys is essential to establish property rights. Therefore, there is a need for navigational systems to permit position accuracy in the order of 50 feet up to 200 miles from shore.

Oceanography 1966, Report of the Committee on Oceanography, National Academy of Sciences (NASCO). This group recommended that a systematic effort be made to understand the ecology of larval and juvenile st- -s of important fish and shellfish species through adulthood. NASCO suggested one laboratory initially, expanding to at least four within five years: One in Atlantic cold water, one in Atlantic warm water regimes, and one each in Pacific cold water and warm water regimes.

Figure 4. *Sharks being tagged by Fish and Wildlife Service biologists at Sandy Hook Marine Laboratory, New Jersey. Research is needed on the life cycle of coastal fish populations. (Trenton Times photo)*

Although NASCO did not specify whether the work would best be accomplished by either expanding facilities and activities at existing laboratories or by constructing new laboratories, the panel believes that the more effective approach would be to enlarge existing centers and where necessary to establish small coastal laboratories dedicated to regional estuarine systems and having affiliations with both State coastal authorities and State academic institutions.[17]

We recommend that two marine preserves be established on each coast reserved for ecological baseline studies. These areas should be identified by the National inventory and studies now being conducted by the Department of the Interior. They should be managed by the Federal Government.

II. THE NEED FOR FEDERAL SURVEYS AND PROJECTS

Management and development of the coastal region will require data which broad Federal surveys are able to provide. However, they should not replace more detailed and continuing studies at the State or regional level that focus on individual problems.

The Federal Government often must take the initiative to demonstrate feasibility or develop new technology in projects for which only it may have the resources or funding capability.

[17] See Section III of this chapter and Chapter 6. See also the Report of the Panel on Basic Science.

A comprehensive discussion of all Federal surveys of importance to the coastal zone is not possible here. Singled out for recommendation are a few of special significance.

The Commission Panel on Marine Engineering and Technology has recommended a series of National Projects, of which many bear on the coastal zone. Only one of those—lake restoration—is discussed here.

Recommended for close attention are the existing or proposed National surveys and projects in the following areas:

—A comprehensive National Coastal Inventory and Survey

—A National Shoreline Erosion Survey

—National Port Requirement Survey

—Great Lakes Restoration Project

A. A Comprehensive National Inventory and Survey

Under the provisions of the Clean Water Restoration Act of 1966[18] the Federal Water Pollution Control Administration of the Department of the Interior presently is conducting a National Estuarine Pollution Study. The act directs that:

(1) The Secretary shall . . . conduct . . . comprehensive study of the effects of pollution, including sedimentation, in the estuaries and estuarine zones of the United States on fish and wildlife, on sport and commercial fishing, on recreation, on water supply and water power, and on other beneficial purposes. Such study shall also consider the effect of demographic trends, the exploitation of mineral resources and fossil fuels, land and industrial development, navigation, flood and erosion control, and other uses of estuaries and estuarine zones upon the pollution of the waters therein.

(2) In conducting the above study, the Secretary shall assemble, coordinate, and organize all existing pertinent information on the Nation's estuaries and estuarine zones; carry out a program of investigations and surveys to supplement existing information in representative estuaries and estuarine zones; and identify the problems and areas where further research and study are required.

(3) The report shall include, but not be limited to . . . (A) an analysis of the importance of estuaries to the economic and social well-being of the people of the United States and of the effects of pollution upon the use and enjoyment of such estuaries; (B) a discussion of the major economic, social, and ecological trends occurring in the estuarine zones of the Nation; (C) recommendations for a comprehensive national program for the preservation, study, use, and development of estuaries of the Nation, and the respective responsibilities which should be assumed by Federal, State, and local governments and by public and private interests.

The act authorizes $1 million for each of three years for the study. The report is due Jan. 30, 1970. In its definition of estuaries the act does not include the Great Lakes.

Public Law 90-454[19] enacted Aug. 3, 1968, directed that:

(a) The Secretary of the Interior, in consultation and in cooperation with the States, the Secretary of the Army, and other Federal agencies, shall conduct directly or by contract a study and inventory of the Nation's estuaries, including without limitation coastal marshlands, bays, sounds, seaward areas, lagoons, and land and waters of the Great Lakes. For the purpose of this study, the Secretary shall consider, among other matters, (1) their wildlife and recreational potential, their ecology, their value to the marine, anadromous, and shell fisheries and their esthetic value, (2) Their importance to navigation, their value for flood, hurricane, and erosion control, their mineral value, and the value of submerged lands underlying the waters of the estuaries, and (3) the value of such areas for more intensive development for economic use as part of urban developments and for commercial and industrial developments. This study and inventory shall be

[18]Section 5(h) of P.L. 89-753 amending the Federal Water Pollution Control Act 33 U.S.C. 466 *et seq.*

[19]82 Stat. 625-628. This is the final version of the proposed H.R. 25 of the 90th Congress. The law provides for a National estuarine inventory and study and for Federal management of estuarine areas with State approval.

carried out in conjunction with the comprehensive estuarine pollution study authorized by section 5(g) of the Federal Water Pollution Control Act, as amended, and other applicable studies. (b) The study shall focus attention on whether any land or water area within an estuary and the Great Lakes should be acquired or administered by the Secretary or by a State or local subdivision thereof, or whether such land or water area may be protected adequately through local, State, or Federal laws or other methods without Federal land acquisition or administration.

This act authorized $250,000 for each of two years and the report is due Jan. 30, 1970.

The goals envisioned in each of these items of legislation appear broad enough to meet adequately the need we foresee. The panel has monitored closely the progress of the National Estuarine Pollution Study. We recommend that the new survey—especially now with its authority to include the Great Lakes—*supplement* and not attempt to duplicate what already is being done.

In order to achieve the broad purposes of the legislation, it is important that the depth of the study cover all aspects of the conservation and utilization of the coastal zone. Balanced consideration should thus be given to potential for commercial, industrial, recreational, and urban development, and to other factors affecting the contribution of these areas to the National welfare. The Secretary of the Interior obviously has the authority to accomplish these broad objectives.

B. A National Shoreline Erosion Survey

New legislation of the 90th Congress[20] directed:

. . . That the Chief of Engineers, Department of the Army, under the direction of the Secretary of the Army, shall make an appraisal investigation and study, including a review of any previous relevant studies and reports, of the Atlantic, Gulf and Pacific coasts of the United States, the Coasts of Puerto Rico and the Virgin Islands, and the shorelines of the Great Lakes, including estuaries and bays thereof, for the purpose of (1) determining areas along such coasts and shorelines where

[20]Section 201 of the River and Harbor Act of 1968, P.L. 90-483, 82 Stat. 731, Aug. 13, 1968, (formerly S. 1262). This is authorization only; no funds have been appropriated.

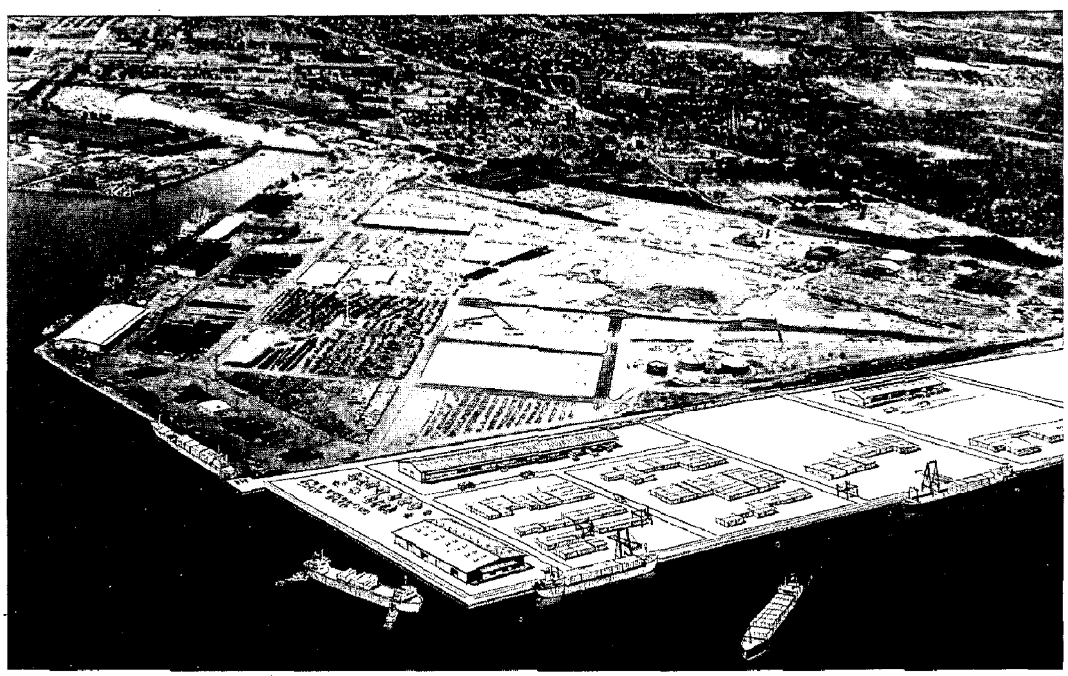

Figure 5. *A modern container terminal is being constructed at an abandoned airport in Baltimore harbor. Modern port development may free large areas of obsolete port facilities for other public uses. (Port of Baltimore photo)*

significant erosion occurs; (2) identifying those areas where erosion presents a serious problem because the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic and other relevant factors, indicates that action to halt such erosion may be justified; (3) describing generally the most suitable type of remedial action for those areas that have a serious erosion problem; (4) providing preliminary cost estimates for such problem areas for action to stop erosion; (5) recommending priorities among the serious problem areas for action to stop erosion; and (6) providing State and local authorities with information and recommendations to assist the creation and implementation of state and local coast and shoreline erosion programs.

The study should contribute significantly to the Federal and State solution of the erosion problem. The Corps of Engineers estimates that about $1 million is required for this study. Funding should be made available as soon as possible.

The Federal Government appears to be assuming the greater share of costs in projects involving shoreline protection when benefits may be disproportionately local.[21] We recommend that the proposed study include re-examination of the formulas for Federal-local sharing as well as for the "benefit-cost" ratio system for justifying projects.

C. National Port Requirements Survey

Future trends in shipping and integrated concepts for general transportation (i.e., larger ships, deeper drafts, containerization, higher speeds, rapid turn-around etc.) may pose requirements competing even further for estuary use. New concepts in port development may, in many instances, indicate that improved port design and location would relieve an estuary of this vital but conflicting influence. The size and hazards of oil and exotic cargoes may well dictate new concepts of loading facilities.[22]

Because of funding procedures, it has been relatively easy to obtain harbor development projects which often exceed the real need of the community. In the resulting dredging, leveeing and diking, many important estuarine resources are destroyed and valuable recreational areas displaced.

A need exists for a National Port Survey to be conducted with the cooperation of the Departments of Transportation, Army, Commerce, and Housing and Urban Development to define the Nation's requirements in terms of major ports, offshore terminals, and other facilities for maritime commerce. On the basis of this survey, a rational scheme for port and harbor development can be established against which the real need for other harbors can be measured.

Such a study should examine closely the Federal-local cost sharing relationships, with an intent to require a proposed port area to be a stronger participant in developing of its facilities.

The Corps of Engineers has proposed that as a lead agency it conduct a regional harbors study with goals similar to those outlined herein. The Corps is conducting, in cooperation with the Committee on Multiple Use of the Coastal Zone of the National Council on Marine Resources and Engineering Development, an initial fact finding study on port modernization. Other Federal agencies as well as port authorities and appropriate State-local interests are cooperating in the pilot study.

The lead agency to conduct a major study should be selected with care. An agency whose mission relies on or is enhanced by port facilities may not be a logical choice. The expertise involved should view transportation as a total system and not just ships and docks. The Corps of Engineers, Maritime Administration, Economic Development Administration, and Coast Guard all have apparent advantages and disadvantages.

Considering all factors, we recommend that the most appropriate would be a multi-agency study headed by the Secretary of Transportation.

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[21] The earliest Federal legislation in beach erosion in 1930 provided for 50 per cent Federal funding for planning and no Federal funding in works. In 1946 this was amended for Federal participation to one-third the cost of construction. Since 1946 it has been steadily liberalized to Federal funding up to 70 per cent (An act authorizing Federal participation in the cost of protecting shores of publicly owned property, Aug. 13, 1946, 60 Stat. 1056 (33 U.S.C. 426-426h) as amended by P.L. 84-826, 87-874, and 89-298.)

[22] See Chapter 5 for a detailed discussion of the problems faced by ports and marine transportation.

D. Great Lakes Restoration Project

The five Great Lakes demonstrate misuse and abuse of the environment by man. Total population in the drainage basins around each of the lakes corresponds closely to the degree of pollution. Lake Erie exhibits the greatest impairment, followed by Lake Ontario, Michigan, Huron, and Superior. Further, the rate of population growth reflects the rate of accelerated aging or *eutrophication* processes in the lakes.[23] If corrective action is not taken, further deterioration will parallel future population growth.

Various restorative techniques which have been considered include removing the organic material, slowing the growth rate or increasing the oxygen supply. Specific suggestions include:

–Sealing bottom samples

–Flushing with low nutrient water

–Nutrient removal

–Thermal destratification

–Dredging

–Biological and chemical controls

–Prevention of light penetration

–Rough fish removal.

Of the various alternatives, the one which might be most seriously considered is *thermal destratification.*

It must be emphasized that the restoration of a lake as large as Lake Erie represents a major environmental modification and, hence, must be approached with caution. Analysis and evaluation required before such an undertaking are beyond the scope of this discussion. Although much of the information necessary to evaluate the feasibility, engineering requirements, and effects of an artificial recirculation project already exists, a great deal of additional work is required.

A project of this type is discussed in detail in the Report of the Panel on Marine Engineering and Technology. The cost of such a demonstration project is estimated at $30 million.

[23]Eutrophication, especially the effects in the Great Lakes, is discussed in detail in Chapter 3.

Based on the information which has been made available to the Commission,[24] we recommend experimental programs in lake restoration leading to an attempt to restore Lake Erie.

III. THE NEED FOR RESEARCH AND TRAINING

Effective management and development of our coastal waters, lands, and resources require that man understand and predict the consequences of his actions. With regard to the nearshore marine and lake-coast environment, too often he is unable to do so.

To implement the acquisition of necessary knowledge, there is a need for the establishment of coastal zone research institutions in association with appropriate academic institutions. They would provide basic understanding of and training in coastal and estuarine processes on which Federal, State, and local governments could rationally base their management procedures. The research institutions need not be large in size but should have adequate facilities and staff to maintain a stable program.

There is sufficient difference between estuarine and coastal problems from area to area, and these problems are of such fundamental importance, that a university affiliated laboratory devoted to basic and applied marine science should be located on every major estuarine system. The relationships of oil wells to shrimp and oyster fisheries in Louisiana differ from those of pulp mills and salmon fisheries in Washington, and the cold water organisms of the Maine coast have ecological tolerances that differ from those of the warm waters south of Cape Hatteras. Such problems are better attacked in university centers in their respective States than through a central Federal or university- National laboratory.

Although problems differ sufficiently from area to area to require different groups studying individual areas, many problems are common to all, and a degree of specialization within laboratories is

[24]In its concern over the eutrophication of the Great Lakes the Commission contracted with the Pacific Northwest Laboratories of Battelle Memorial Institute for a brief review of the potential of Great Lakes restoration. The report of the contract is contained in *Great Lakes Restoration–Review of Potentials and Recommendations for Implementation,* Pacific Northwest Laboratories, Battelle Memorial Institute, June 17, 1968.

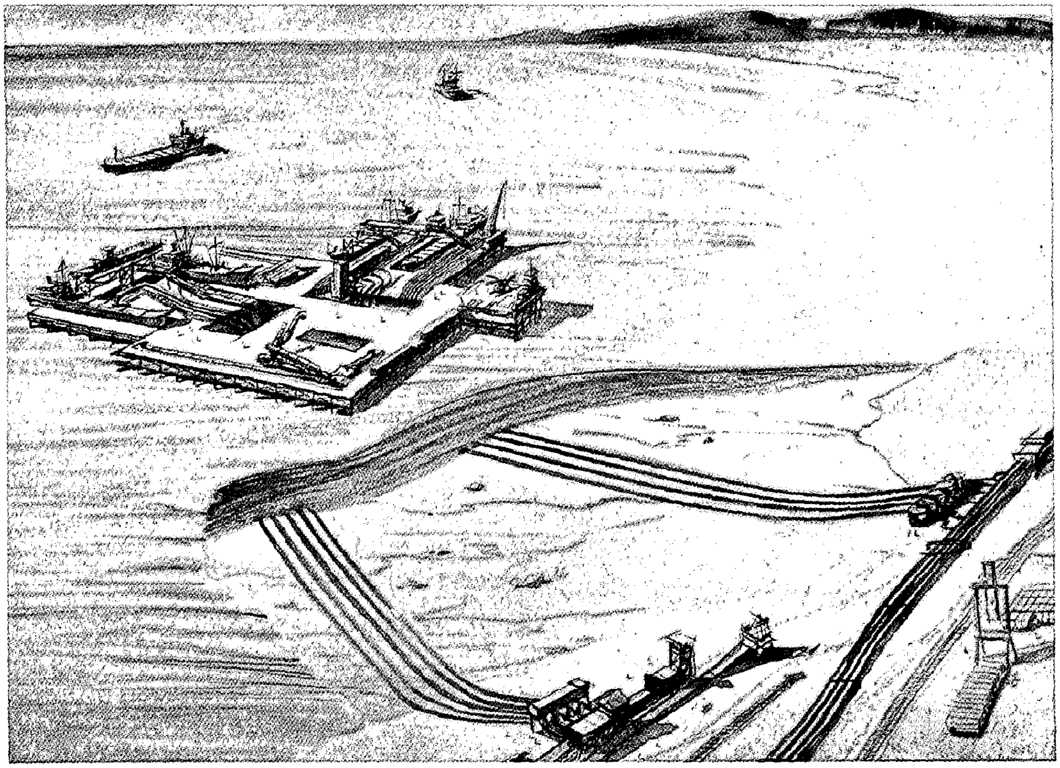

Figure 6. *Artist's conception of an offshore loading terminal. Such bold new actions may relieve existing ports of conflicting pressures and expensive port redevelopment.*

not only inevitable but desirable. A complex computer simulation model may be developed for one estuary, but once developed may have more general applicability. Laws governing turbulent diffusion processes are similar, although their application may vary considerably from case to case.

The National Sea-Grant College and Program Act of 1966[25] provides a mechanism for supporting the complex of coastal zone laboratories envisioned. First, the problems are not in the natural sciences alone but in the social sciences as well. Second, many of the problems are "applied" and are in urgent need of a solution. Third, the State has an important interest in the solution of these problems and the training of its people and should be expected to share in the program. These coastal zone laboratories should provide the studies and research on which the State may base its management decisions.

[25] P.L. 89-688, Oct. 15, 1966, 80 Stat. 998 33 U.S.C. 1121-1124.

The coastal zone laboratories should be operated under the Sea-Grant College Program, which would provide the necessary resources and expertise that the States do not now have. Although the relationship of State government to local universities differs from State to State, it is usually closer than that between the State government and Federal laboratories. The relationship between a university laboratory and State government will not and should not be identical with that between a Federal agency and its research laboratories. The States will have to maintain their own management and enforcement system and in some cases their own estuarine environmental monitoring system.

The resources of the university-coastal zone laboratories will be available for research, special studies, and assistance just as are those of the agricultural experiment stations and the extension services operated by land-grant colleges. Accordingly we recommend that Sea Grant funding for coastal zone research be increased over the next 10 years to provide, in addition to other Sea Grant programs, institutional support for 30 coastal laboratories at an annual rate of about one-half million dollars each. In addition to institutional support for coastal zone laboratories, we recommend Sea Grant funding be increased further to support research problems and manpower training related to the coastal zone at an annual level of about $12 million.

IV. THE NEED FOR PLANNING AND MANAGEMENT

As a Nation, we are faced with a crisis in the effective use of the coastal zone. The rapidly growing population along our coasts and Great Lakes is accompanied by accelerated development, which often thoughtlessly intensifies pollution and degrades the environment. Conflicts among some uses are increasing—or are becoming increasingly apparent—and random choices render the environment inhospitable to other concurrent or future uses. Indeed, severe damage to the environment can preclude its return to the previous natural state. Other new uses may require efforts of restoration at great time and expense.

In many—perhaps most—cases, uses have evolved with little advance planning, little examination of conflicts or consequences, and hence without adequate consideration of long-term effects on the environment. These have been identified and discussed in previous chapters.

Many uses are subject to a variety of public and private actions and fall into several often overlapping government jurisdictions. Mute testimony to this is the size of Chapter 7 and its description of Federal agencies.[26] The picture is typically one of uncoordinated efforts to achieve various objectives in the coastal zone.

With responsibility fragmented, with little incentive for affected interests to submit to anything like a single manager, with a multitude of objectives that may be pursued, it is particularly difficult for plans to be designed, made authoritative, and enforced.

To a substantial extent, simultaneous use of the zone for many purposes is possible, provided that it is planned for. Effective planning necessitates developing an understanding of the coastal ecology and the dynamics of coastal processes far deeper than available today. It calls for an analysis of economic activities and their inter-relations. It requires such criteria as State water quality standards to protect the utility of the resource. It includes protection of the shoreline and of adjacent waters. Effective planning includes the exercise of sound land use principles.

Purposes that find easy expression in immediate economic returns should not predominate in guiding choices. Instead, special efforts are necessary to plan for the future and to consider intangible benefits difficult to evaluate in the usual economic terms.

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[26]See also the Commission contract report, *A Perspective of Regional and State Marine Environmental Activities: A Questionnaire Survey, Statistics and Observations,* John I. Thompson & Co., Washington, D.C., Feb. 29, 1968.

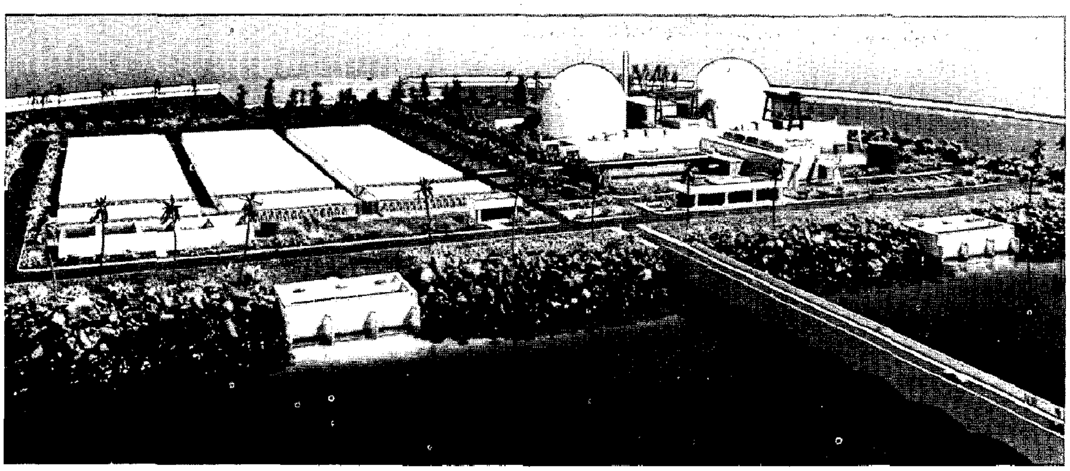

Figure 7. *Artist's conception of the proposed Bolsa Island dual-purpose nuclear power and seawater desalting plant off Southern California. Bold new projects as this are symbolic of future use of the coastal zone. (Office of Saline Water photo)*

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The concept of multiple use of public resources implies that Government will serve as resource manager in the coastal zone. As such, Government considers alternative ends for ocean development, considers alternative means to accomplish these ends, and further, defines criteria for deciding among them.

Managing the resources will be a complex task. For one thing, no one government agency either Federal or State has, or is likely to have, unified management responsibility for all aspects of ocean development. For another, the several industrial and nonindustrial interests have different goals and approaches to coastal development.

Finally, various regions of the sea and the resources within each region have their own special characteristics. Effective management further requires a proper legal framework.

We believe the central criterion in any planning should be to balance potential uses and users. The best assurance of including this criterion in the planning and decision-making process for the coastal zone is participation of varied interests in allocating uses and in judging among specific competing uses.

Although the level of government involvement should be determined by specific circumstances, in general, State leadership is to be favored. Large, interstate estuaries may require interstate compacts. Metropolitan areas may well require special kinds of governmental units such as regional or council type governments currently under discussion.[27]

It also is important to recognize the role of National interests vis-a-vis local interests. Planning and implementation of coastal management may need to include National, as opposed to regional, interests. The most important sources of this interest are: (1) preservation of unique natural areas, (2) the vital role of many estuaries in supporting populations of migratory waterfowl and fish, (3) interstate navigation (4) National defense, and finally (5) the coastal zone as a National resource. These reserve the right of the Federal Government to review the efficacy of any management system.

In Chapter 10, we outline in some detail our recommendations for State Coastal Management Authorities.

V. THE NEED FOR A SYSTEMATIC APPROACH TO WASTE MANAGEMENT

One of the traditional uses of our rivers, Great Lakes, estuaries, and open coast has been waste disposal. Every body of water can assimilate wastes to some extent with little effect on the ecology or the condition of the lake, river, or estuary. But every body of water, including the ocean, has a limit.

The panel has had difficulty in coming to grips with the pollution problem in the marine environment. In many of the coastal zone areas it is the single most important problem. It is the one problem in which there is the most action at all levels of government. It is evident that the people of this Nation are disturbed about pollution and they aim to do something about it.

Throughout this report we have noted problems related to water quality, oil pollution, the need for more sewage treatment plants, and the almost insuperable task of controlling insecticides and other non-point source pollutants. We have made a series of specific recommendations concerning pollution and have noted with satisfaction the increased public awareness of pollution problems and the progress in pollution abatement made in recent years. The President now has advisory boards on both air and water pollution. Water pollution problems are the concern of several Federal agencies as well as the interagency Water Resources Council.

In spite of all of this activity, however, the panel is not sanguine about the future. Problems of waste management are not simply a combination of air, water, and land pollution problems. Much which is basic to our economy is involved in waste management. It is certainly more efficient and, in an absolute sense, more economical, to remove dirt before it leaves the smokestack than to shovel if off the streets or scrape it off the sides of buildings. The man who sprays his fields is not responsible for the pesticides that drain off into

[27] Advisory Commission on Intergovernmental Relations, *Alternative Approaches to Governmental Reorganization in Metropolitan Areas* (1962), p. 85. The latest commentary and draft law on councils of government are to be found in Advisory Commission on Intergovernmental Relations, *1967 State Legislative Program of the Advisory Commission on Intergovernmental Relations* (1966).

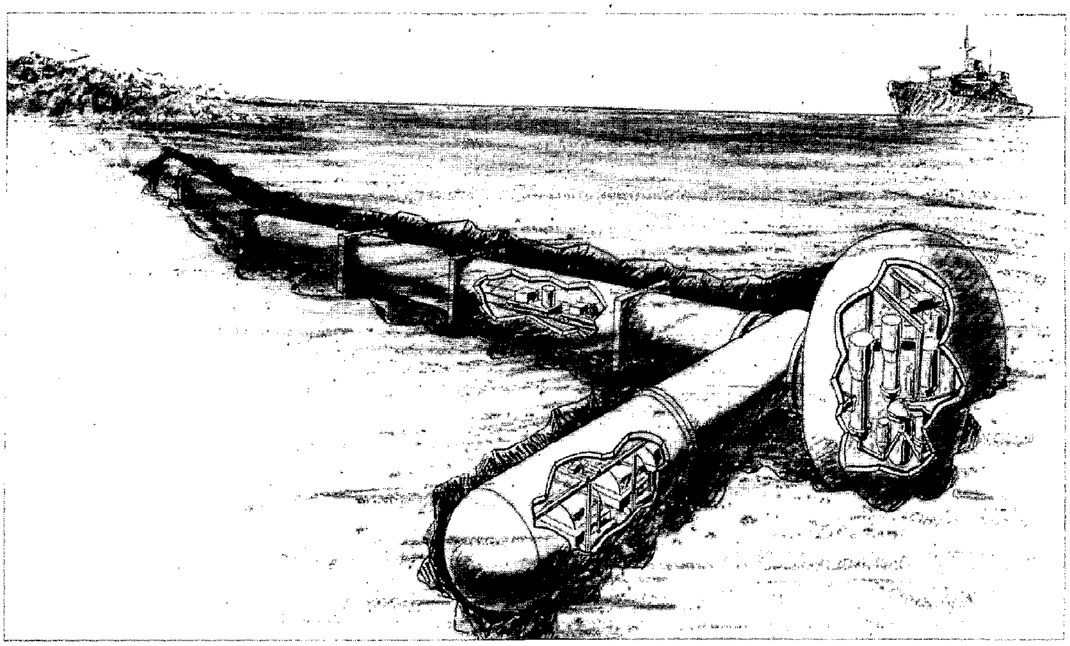

Figure 8. *Artist's conception of a continental shelf nuclear power plant. The location of such plants may relieve the pressure of land use conflicts on the coast and better provide for cooling and dispersal of waste heat (Westinghouse photo)*

the streams, and there is little economic incentive to find alternative solutions. Burning wastes rather than dumping them in a river does not solve the pollution problem; it merely changes the nature of the problem.

Recommendations concerning problems such as these lie beyond the authority of this Commission. Even if we had so interpreted our mandate to consider this class of problem, to study them with the diligence they deserve would mean that we would have done little else. We do, however, concur with the National Academy of Sciences and PSAC reports in the belief that any lasting solution must consider waste management as a total system.

In many respects the conditions confronting those who wish to establish a National waste management policy are similar to those that created this Commission on Marine Sciences. There is tremendous public interest; there is a feeling of urgency; there is fragmented authority; and there is a feeling that if this Nation wishes to make the commitment, significant results can be obtained. If technology is responsible for many of our pollution problems today, technology can help in solving those problems tomorrow if given the opportunity and incentive to do so. The panel believes that a total integrated approach to the problems of waste management is necessary. Although detailed recommendations on these matters are beyond the scope of our activity, we recommend that there be established a National commission to study and deal with the total waste management problem.

In Chapter 9 and in earlier chapters we have presented the need for effective management of our coastal and lakeshore zones. In this chapter we recommend a program involving a Federal-State partnership to manage and develop the coastal zone. The goal of this program is:

To achieve in our coastal waters a quality of environment which will ensure economic development, and sensible utilization of our resources through Federal-State cooperation in sound planning and management.

The program developed here envisions management vested in a State Authority or in a State established local or regional authority. The general role of this authority would be to undertake, in participation with other State and local authorities, the planning, regulation, and acquisition of coastal and lakeshore waters and lands.

Implementation of this program requires Federal legislation to define National objectives, set forth policy guidelines, and authorize funds for Federal assistance. It is not feasible that legislation be binding on any State. However, the legislation should encourage States to participate. A State which benefits from Federal funding incident to this program would be a participating member of the program.

A "participating" State means that the State has established a State Coastal Zone Authority subject to the review and approval of the Federal Government. The form and detailed functions of the State organization are at the discretion of the State concerned. The agency could vary from a powerful Statewide central authority to a local bi-county regional authority dedicated to a single coastal or estuarine region. Although more modest, the latter would allow an area-by-area implementation and at the same time preserve the balance of local powers.

The role of the Coastal Zone Authority would be:

—To plan for multiple uses of the coastal and lakeshore waters and lands

—To resolve conflicting actions through regulation, zoning, and/or acquisition

—To maintain a continuing inventory and studies and to sponsor and conduct research as a contributing link in decision making processes

The Federal role following enactment of legislation would be to provide assistance in the form of a broad National inventory, funding grants, and review of State and local effectiveness to establish the basis for continued Federal funding. Under this program the Federal Government has available two mechanisms to induce positive and progressive State and local action: withholding Federal grants and acquiring and managing areas determined by the Federal Government to be endangered and critical to the National interests but not protected adequately.

Areas under Federal jurisdiction should be under Federal management and development except where the Federal Government has expressly ceded jurisdiction to a State or government unit under State authority.

Figure 1. *The coastal zone is a National resource and its use should be administered in the public interest. (National Park Service photo)*

I. NATIONAL INTERESTS

National interests are the aggregate objectives, policies, and activities through which we seek to accomplish the goal. Objectives of a coastal management program can be expressed in the following terms:

—To understand the natural processes occurring in the nearshore environment and thus to predict man's effects on this environment

–To use the environment to the benefit of man

–To accommodate with minimum conflict multiple uses of the environment

–To maintain, and restore if necessary, the environment at a level of public choice for both the present and future

Policy guidelines for the Coastal Zone Authorities would incorporate the following principles:

–Coastal zones should support the widest possible variety of beneficial uses and be managed to maximize net social return. This means that unless necessary in the broad public interest, no single use–such as waste disposal–or class of uses–such as commercial uses–should be allowed to exclude other beneficial uses

–The Coastal Zone Authority should represent a balanced approach. For example, it should not be dominated by either conservation or economic development groups.

–There must be an opportunity for public hearings to allow local governments, private interests, and individuals to express their views before actions are taken or decisions made to change or modify uses of the coastal zone. Decisions of the Coastal Zone Authority should become a matter of public record.

–There must be a mechanism for the input of Federal, State, and local governments in the determination of shoreline use within the coastal zone.

–All actions within the coastal zones and in the contiguous zone must respect Federal rights as well as international agreements. Any proposed action must not violate water quality standards established by the States in accordance with Federal law. Planned uses of coastal waters must be the basis for establishment or revision of such standards.

–In the case of interstate estuaries, the programs of other States must be considered to provide coordinated action.

Activities through which we attempt to achieve the objectives also define the National interests. These include:

–Undertaking basic and applied research in the coastal environment and in disciplines relevant to marine activities (physical and chemical processes, ecological research, socio-economic trends, etc.)

–Facilitating development of technologies pertinent to coastal activities (shoreline stabilization, transportation, safety, aquaculture, recreation, etc.)

–Operation and maintenance activities (providing safety services such as search-and-rescue operations, certification and standards, navigation, cartographic services, etc.)

–Regulating and administering activities (resolution of conflicts, coordination of public and private roles, distribution of net benefits, establishment of a legal framework, etc.)

–Educating and training personnel to ensure a continuity of effort and progressive achievements.

II. PROPOSED LEGISLATION

Federal legislation is required in order to achieve the stated objectives. Such legislation should:

–Define the National policy and objectives

–Call for the States to establish statewide or local coastal authorities or equivalents

–Set forth broad policy and guidelines for operations and powers of State authority(ies)

–Establish the Federal interface

–Provide Federal assistance in the form of grants, research, and technical assistance

–Impose a Federal review of program activity and provide for curtailing Federal assistance in the case of non-compliance with standards

–Authorize funds.

Such management systems are now in effect, for example, the Federal Water Pollution Control Act,[1] under which States have primary responsibility for "zoning" rivers and waters through the

[1] 33 U.S.C. 466 *et seq.*, P.L. 84-660, as amended.

medium of water quality standards. In this act the Federal Government sets National objectives and provides technical expertise and various kinds of financial assistance, and provides for enforcement when the States do not act.

The Water Resources Planning Act[2] is another example. Here River Basin Commissions are authorized to be established by States or interstate compacts and Federal funding assistance is provided. The Federal interface is the Water Resources Council.

In order that new legislation may most effectively take its place in the family of related Federal legislation, it may be desirable to amend several laws bearing on coastal resources and development. Amendments might range from increased funding to transfer of power or priorities. Some of these laws are:

–Rivers and Harbors Act[3]

–Federal Water Pollution Control Act[4]

–Fish and Wildlife Coordination Act[5]

–Federal Aid in Fish Restoration Act[6]

–National Sea Grant College and Program Act[7]

–Water Resources Planning Act[8]

–Land and Water Conservation Fund Act.[9]

The sections following treat in greater detail various aspects of the proposed legislation and its intent. For the sake of illustration a highly simplified version of sample legislation is presented in Appendix F.

III. THE FEDERAL ROLE

Although this management scheme places most of the responsibility within the States, many well-established Federal interests in these areas remain: navigation, waterways, and National resources such as parks, wildlife, etc. Federal agencies administering such programs can be expected to interact separately with the Coastal Zone Authority. However, the tasks of Federal funding, assistance, and review should be vested in one agency. Under present Federal organizational structure, the most appropriate Federal interface would be either the Secretary of the Interior or the Water Resources Council.

IV. POSSIBLE STATE MANAGEMENT SYSTEMS

The intent of the National program is that the State respond to Federal legislation by establishing or otherwise redirecting government bodies or authorities that would accomplish the jobs to be done. Legislation spells out only the objectives, not the specific means to accomplish them. Thus it rests with a State to determine the makeup of its organization. A State's options range from creating a statewide agency to creating a local authority for a particular region. The latter appears to have certain advantages:

–It may more readily fit in with existing local authorities

–It would be more responsive to the particular problems of a region

–It would permit a State to establish regional authorities on a step-by-step basis according to needs.

Another option in setting up a State coastal management authority is the creation of a special district along the lines of a metropolitan sanitation district or port authority. Such a district could be established easily by State legislatures. The district would cause minimum disturbance to existing units of government. Its concern would not be diluted by that for other regional problems.

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[2] P.L. 89-80, approved July 22, 1965.

[3] Rivers and Harbors Act of 1899, 33 U.S.C. 403-407. This act provides for Federal controls over dredging and filling navigable waters, dumping refuse, and obstructions. See Chapter 3, Section A.

[4] P.L. 84-660, as amended, 33 U.S.C. 466 *et seq.* See Section I of chapter 9.

[5] Act of March 10, 1934, 48 Stat. 401, 16 U.S.C. 661-666c. See Section I of chapter 9.

[6] Act of August 9, 1950, 64 Stat. 430, 16 U.S.C. 777. See Chapter 2, section X.

[7] P.L. 89-454, 33 U.S.C. 1121-1124. See Chapter 9, Section I.

[8] Water Resources Planning Act, P.L. 89-80, 79 Stat. 244. This act provides Federal grants to States for water resources planning. It also authorizes River Basin Commissions as planning bodies.

[9] Act of September 3, 1964, 78 Stat. 897, 16 U.S.C. 4601. This act provides for funding State and Federal planning and for acquisition and development of waters and lands used for recreation and conservation purposes.

But such a district would have problems common to all special-purpose government agencies. It would be difficult to create a governing body truly responsible to the regional public. Funding would be difficult. It would continue the proliferation of government agencies, bringing further fragmentation of public authority and increasing unnecessary competition among governments for funds and power.

Alternatively, a multi-purpose government agency could be created with responsibility not only to carry out coastal plans but to solve other regional problems: solid waste disposal, acquisition and operation of regional parks and open space, control of air and water pollution, and area-wide transportation needs. A comprehensive agency could weigh a region's various needs, allocating priorities to programs of greatest importance and striving for a balance among them. A multi-purpose agency could do a better job of coordinating and accommodating competing uses.

Such an agency would be more difficult to create than a single-purpose district because it would incur resistance from agencies or units of government that might be modified or absorbed into the comprehensive agency.

Examples of existing agencies are the San Francisco Bay Conservation and Development Commission[10] and the Oceanographic Committee of the Nassau-Suffolk Regional Planning Board (New York).[11] Established primarily for planning purposes, each was given sufficient powers to affect its respective area profoundly. Both have recommended establishment of a regional authority.

In the final analysis, the form and make-up should be left to the State, but Federal and local government interests must be safeguarded.

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[10]The San Francisco Bay Commission was established (BCDC) by the State legislature in 1965 to prepare a comprehensive and enforceable plan for conservation of the waters of the Bay and development of the shores. During its administration it was granted management powers. The Commission has produced a series of 22 authoritative reports. The tentative recommendations of the BCDC include a regional agency with powers to plan and regulate the Bay as a unit. See Appendix D.

[11]The Oceanographic Committee of the Nassau-Suffolk Regional Planning Board was established in 1965 by the two Long Island, New York counties. Having no absolute powers, its authority is derived from an export advisory capacity in planning, zoning, and regulatory matters of the bi-county coastal zone. Its first report is entitled *The Status and Potential of the Marine Environment,* December 1966.

V. COASTAL ZONE AUTHORITY

Development of the coastal management system proposed by this report envisions that the action role be vested in the State through a State agency which we call a Coastal Zone Authority.

The functions of the Coastal Zone Authority are:

–Planning the utilization of coastal and lakeshore waters and lands

–Encouraging the development of these areas in the public interest

–Resolving conflicts through public processes: regulation, zoning, and acquisition

–Studies and continuing research to maintain plans and decisions with requirements and trends.

The magnitude of coastal problems varies with the area, and States will evolve different ways of handling them. As noted in the previous section, not all Coastal Zone Authorities need or should have the same form. However, regardless of the form of authority, guidelines must be responsive to public interest and National policies set forth earlier.

An agency or authority thus established would serve to convert the National interests into action programs. It should possess the following powers:

–Planning–authority to continue research and planning necessary for informed decision-making

–Regulation–power to grant or withhold permits for coastal land and water use and, in addition, some authority to require that lands adjoining the coastline be used for purposes compatible with its overall plan

–Acquisition and eminent domain–authority to buy lands when public ownership is necessary and to acquire such lands through condemnation if necessary.

–Development–authority to provide, either directly or by arrangement with another government agency, such public facilities as beaches, marinas, and other waterfront developments and to lease offshore areas.

The three functions: *planning, regulation,* and *acquisition* were discussed in detail in Chapter 8. They are briefly discussed here as applicable to the powers of a Coastal Zone Authority.

A. Planning

A State's first step is to develop a comprehensive or "master" plan to coordinate use of land and water resources. This can be accomplished by the State authority or authorities whose functions are spelled out by State action or by a temporary planning commission whose duties are to develop the plan and recommend the nature of an authority or agency necessary to fulfill the State role. At this level it should strive to coordinate local planning, both public and private, with planning at the area-wide level. The planning agency should establish close relationships with other institutions concerned with area-wide development: water supply and development authorities, mass transportation agencies, special districts, highway departments, park and recreation agencies, and air pollution control bodies.

The panel found that a great amount of planning for general land and public use presently exists, much conducted under the Urban Planning Assistance Program authorized by Section 701 of the Housing Act of 1954. Full benefit should be taken of such planning wherever possible.

Federal funding for functional and action programs should be contingent on Federal review and approval of a comprehensive area-wide plan.

B. Public Regulation

Effective management of a coastal region requires government action. Regulation offers one means of implementing a plan to conserve and develop shorelines; acquisition offers another. Implementation depending solely on acquisition might prove too costly. Moreover, widespread acquisition would result in a government agency owning, and thus having to administer, large areas of shoreline. Yet regulation should not be the sole implementing tool.

Regulation assumes that private owners will retain title to their lands, but that uses and development will be restricted by legislation. The most typical contemporary land regulation systems are zoning and regulation by permit.

C. Zoning

In the past the owner of land could do with it whatever he wanted. He was constrained if his activities produced damage to his neighbors or created a nuisance for which he could be brought to court. Out of this developed a system of zoning which, by planning, tried to minimize interference between adjacent (or close) users of land in a community.

But zoning for land uses is different from zoning for water uses. The difference arises from the concept of "range." The range of interference for land uses is very short, while that of water uses can be quite large; for example, pollution at one point in a body of water can be carried to another easily. (This reasoning also applies to air pollution.)

The larger "range" of zoning is recognized by the Federal Water Pollution Control Act and by the Water Quality Standards set for rivers, estuaries, and coastal waters, which spell out water use and imply, also, constraints on land use. As a further complication, the "range" can even extend from one estuary to another through the intermediary of migratory fish and migratory waterfowl.

Zoning traditionally is the responsibility of local governments. Historically they have failed to protect the nonmarketable interests—scenic beauty, recreational values, and preservation of wildlife—against economic interests producing jobs and increasing the tax base. For this reason, responsibility for zoning the coastal zone should be at the State level or, if dealing with a portion of a State, under State authority.

Zoning regulations would be designed to implement the comprehensive plan adopted by the State through its Coastal Zone Authority.

D. Regulation by Permit

Alternatively to zoning, a planning body could decide regulation through permits issued according to prestated criteria.

Under this method, activity could proceed only on approval by the Coastal Zone Authority. Regulations could set forth types of development permitted. For instance, such regulations might permit boat yards, marinas, and like uses at designated shoreline locations only if such use were desirable for the public convenience and in harmony with the comprehensive plan. A comprehensive plan could be the basic regulatory document, with permits issued on the basis of its objectives, standards, and other provisions, rather than criteria set forth in regulations implementing the plan.

Such an approach—case-by-case consideration of proposals, applying general statutory criteria fairly—affords several major advantages. First, it provides the agency with maximum flexibility in determining response to concrete development proposals.

Second, such an approach minimizes differential value impacts caused by such precise regulations as zoning. A zoning ordinance indicates which uses are permitted at specified locations. The types of permissible activities affect value. Absence of precise regulation would leave development potential uncertain and thus minimize an artificial inflationary (or deflationary) force.

Third, a permit procedure allows more detailed regulation. The legislation, and the plan's objectives and standards, would invest discretion in the Coastal Zone Authority, which in turn could negotiate with developers the many aspects of proposed development otherwise beyond regulation.

E. Acquisition

Current and projected pressures for public and private recreational development make zoning and permits unrealistic as the only recourse in planning and regulations. The economic pressures of the local tax base and political realities necessitate the availability of other options.

Foremost among these options are easements and acquisition. Least costly, the former is preferred when it can serve such an explicit purpose as protecting aesthetic and cultural values. The latter is the more sure when important conservation, recreation, or public development areas are to be preserved.

The first goal of coastal acquisition would be marshlands and potential public recreation areas. The Federal Government can assist a State when determination of "tidal lines" or "navigability" is the question.

There are several alternative sources for funds:

–State appropriations

–Bond issues (which the Coastal Zone Authority might be empowered to issue)

–License and tax revenues

–Existing Federal assistance programs like Federal Aid in Fish Restoration Act (Dingell-Johnson), Federal Aid in Wildlife Restoration Act (Pittman-Robertson), Land and Water Conservation Fund Act, etc.

–Authorization by new legislation.

All the above funding schemes are sound and could be utilized. In view of the National interest involved, Federal funding is an important source, and funding authorization should be in the legislation enabling this program.

In addition to State acquisition of coastal lands in the public interest, there is the added consideration of Federal acquisition. From the outset Federal acquisition is in the public interest as a part of an established National program. When delegated Federal authority considers a State failing to manage and administer critical coastal and estuarine areas, or when a State is unable to acquire needed lands not already in public ownership, the Federal Government may acquire given areas. Acquisition is one of the two mechanisms the Federal Government has to ensure positive and progressive State action; withholding Federal grants is the second.

F. Research

Effective management and understanding of the coastal zone requires a continuing program of monitoring, inventory, and in-depth studies. Just as Federal agencies have research laboratories to provide continuing studies required to fulfill their missions, the Coastal Zone Authorities require a research arm. Many problems are interdisciplinary, requiring talents which range from physics and biology to civil engineering, resource economics, and sociology. The inventorying and monitoring requirements can best be done by units, dedicated to a local region and responsible to the State authority.

We believe every State should have a research group devoted to the problems of the coastal zone.

This laboratory should be a part of a university or closely affiliated with one.[12]

The relationship of the university to State administrative groups with respect to basic and applied research varies from State to State. However, regardless of the form of the relationship, the existence of a strong, research-oriented group affiliated with a university should provide some of the necessary trained personnel, should provide a state-wide education program, and should bolster the State's administrative ability to formulate plans and to execute a rational policy of administration.

Research support can come from the National Sea Grant Program (P.L. 89-688) or it can be included in the new legislation. Both appear desirable. The goals of the National Sea Grant Program clearly include the same objectives important to understanding our coastal environment.

VI. FEDERAL FUNDING

Federal funding assistance is a vital part of the recommended program for two basic reasons: It serves as a positive inducement for a State to participate in the National program, and it provides a means otherwise unavailable for a State to manage and acquire its coastal lands and waters in the public interest. Although other related Federal funding programs may serve indirectly or peripherally, none accomplishes the full intent of the program proposed. Enabling Federal legislation should provide Federal funding assistance in the following areas:

–*Planning*–the development by States or their designated regional authorities of detailed inventories of shoreline and estuarine resources and comprehensive plans of land and water uses

–*Operations*–expenses for regulatory and enforcement actions including public hearings and office overhead

–*Acquisition*–to bring under public ownership important coastal lands and waters which may not be provided for under other Federal and State programs

–*Development*–for protection and restoration of public shorelines and coastal areas

–*Research and Training* (including a continuing inventory and detailed studies)–Federal funding assistance can be applied to the above categories by formulas spelled out in the enabling legislation.

A. Planning

Federal assistance should be provided through matching grants on a 50 per cent basis[13] to States or their delegated agencies in accordance with Federal regulations. Section 701 of the Housing Act of 1954 and Title III of the Water Resources Planning Act provide planning funding which also can be utilized. New Federal funding for planning is included with operations funding discussed below.

B. Operations

In general the operation of Coastal Zone Authorities should be supported from State or local appropriations only. The reason for this is twofold: (1) because the form of the agency should be left to the State, it may be difficult to identify for Federal funding and (2) if Federal operating funds are withdrawn for failure to comply with National standards, the agency would collapse and be unable to regain its credibility. However, assistance in implementing the agency should be provided and in doing this Federal grants to support the first two years' operations should be authorized from planning grants. For an initial 10-year period, Federal funding for planning and operations by State Coastal Zone Authorities should be at an annual level of $2.5 million[14]

C. Enforcement

The panel has found that the means for enforcement is the single greatest problem facing existing such State authorities as water pollution

[12]See Chapter 9, Section III. Under the need for research and training we have recommended the establishment and support of coastal zone laboratories.

[13]The rationale for the formulae shown here and in subsequent suggested examples was developed from existing legislation which according to the Panel was found through its hearings to be particularly effective and favorable. These include Sea Grant, Federal Aid to Fish and to Wildlife Restoration, and Water Resources Planning Acts.

[14]See Appendix E for development of this total.

agencies. Therefore, Federal grants to State Coastal Zone Authorities for enforcement action appear necessary. Estimates of required funding are difficult to ascertain. A recommended figure is approximately equivalent to that for planning and operations or an annual level of $2 million.

D. Research and Training

In Chapter 9 we recommended the establishment and support of coastal laboratories and research and training in the coastal zone. This should be accomplished through the medium of the Sea Grant College and Program Act of 1966. The level of support should attain a total annual level of about $27 million.[15]

E. Acquisition and Development

Federal funding should be as matching grants on a two-thirds Federal–one-third State basis according to Federal regulations for such projects or combinations thereof if they are in accordance with the State or regional authority comprehensive plan. *Or* the Federal Government may guarantee non-tax-exempt bond issues by the State or State delegated regional authorities provided that the bond issues are in accordance with the State or regional plan and are approved by the Federal Government. Funding in this area is difficult to estimate: The coastal and lakeshore States contain a total of about eight million acres of important estuarine habitat.[16] Maryland and North Carolina each have estimated that about 10 per cent of their coastal areas and marshlands should be in public ownership.[17]

An extrapolation of these figures suggests that about one million acres of coastal lands may need to be acquired. Further, assuming acquisition and matching development costs of $500 per acre, the cost is about $500 million. Further acquisition needed by States may be potential recreation areas outside the qualifications of urban redevelopment of parkland. Such areas would be obsolete port terminals and industrial sites. Here estimates are virtually impossible and can only arbitrarily be set at about 50 per cent additional, or $250 million. The total acquisition costs faced by State Coastal Zone Authorities then becomes $750 million. Considering a Federal share of 66 2/3 per cent of the total, the Federal level of funding becomes $500 million. Extending this over a 20-year period indicates a desired annual level of Federal funding for acquisition and development at about $25 million per year.

VII. FEDERAL REVIEW

Once the Coastal Zone Authorities are established, review is a continuing need. It is imperative that the National interests be protected and if for any reason a Coastal Zone Authority cannot act in the public interest, the Federal Government should participate in the actions of the Coastal Zone Authority. Regardless, the Federal Government should have power of review.

The Federal review role is critical. In our discussions with those active in this area, we found general agreement that the States should manage the coastal zones; they have the responsibility and they have, or at least should have, the detailed local knowledge necessary for sound management. However, there may be times when the local pressures will tend to force the Coastal Zone Authority to act in a manner not in the National interest. The mere threat of Federal review will often suffice. If not, the Federal Government should be empowered to act in the public interest.

Federal review would be accomplished in progressive stages, commencing with State notification that it intends to become a "participant." Here review would simply be examination of the management authority or authorities which the State proposes or has already established. This review and subsequent reviews would be based on objectives and guidelines prescribed in earlier

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[15] As shown in Chapter 9, Section III, this is broken down as half a million dollars institutional support for each of 30 coastal laboratories and overall research support of $12 million. See Appendix E for a more detailed analysis.

[16] Report of the U.S. Fish and Wildlife Service to the Senate Merchant Marine and Fisheries Subcommittee, Oct. 7, 1966.

[17] *Proceedings of the Inter-Agency Council on Natural Resources*, State of North Carolina, Nov. 21, 1967, and *Estuarine Lands of North Carolina: Legal Aspects of Ownership Use and Control*, David A. Rice, Institute of Government, University of North Carolina, April 1968. Also report of Roy E. Walsh, Chairman, Maryland State Board of Natural Resources, to House Subcommittee on Fisheries and Wildlife Conservation, March 9, 1967.

sections and the National inventory[18] which identifies problem areas and Federal-State-local responsibilities. Planning grant and other implementing funds would become available upon approval of a State Authority's program.

The next Federal review stage would consider the comprehensive regional plan or plans. If approved, further grants for acquisition and development would be closely reviewed for compliance with the plan.

Similarly, proposals for bond and loan guarantees would be subject to Federal review.

Upon Federal review determining that administration of a program is not in compliance with National objectives and standards, no further Federal payments will be made to the authority until the Federal review is satisfied.

VIII. MANAGEMENT IN INTERSTATE ESTUARIES

Estuaries or adjacent coastal waters directly affected by more than one State–the Delaware Bay or Potomac River estuary, for example–may pose institutional problems which otherwise would not occur if the same region were entirely within a single State. This is subject to two views:

–Sound planning and management undertaken by one State probably would not differ greatly from an adjacent State. Therefore, interstate waters actually are not a significant problem. When differences do arise, each may be settled on its own merits or through an existing interstate commission or compact.

–Responsibility for management could be vested in a river basin commission or other interstate compact.

The panel has carefully considered the roles of river basin commissions and has concluded that as planning agencies principally devoted to water resources, such agencies are not to be recommended, but that in the few cases where an interstate compact is required, it be established along the lines of the State authorities herein proposed.

[18]See Chapter 9, Section II.

A river basin commission does not have any management or enforcement authority; it only plans and advises. If set up under a compact, however, like the Delaware Basin Commission, it could be granted the necessary authority by the States. An argument for keeping a Coastal Zone Authority distinct from a river basin commission is to use the Coastal Zone Authority as a control on water quality coming into estuarine areas.

The rational solution of interstate problems in the coastal zone is for each State to have a strong Coastal Zone Authority. Interstate problems can be treated by commissions or compacts agreed to by the Coastal Zone Authority. The Federal Government should not be a member of interstate agreements, except to participate as an observer. However, the Federal Government continues to have the power of review, and it can exercise authority if one Coastal Zone Authority requests it in connection with actions of another. In addition, the Federal Government could serve as arbitrator in interstate cases in which the Coastal Zone Authorities cannot agree.

In any case, recommendations of river basin commissions and similar regional planning bodies should be considered in interstate planning.

IX. MANAGEMENT OF THE OUTER CONTINENTAL SHELF

The proposal for a National coastal management program has been limited to the territorial sea and inshore lands and waters because responsibility for the program is vested essentially in the States. With the exception of certain State boundaries in the Gulf of Mexico, State authority extends no farther than three miles offshore.

It has been shown, however, in Chapters 2 and 7, that competing and conflicting uses can be expected to increase on and within Continental Shelf waters and on the sea bottom outside State jurisdictions to which management authorities established pursuant to the proposed program do not apply. The areas then become a management problem for the Federal Government.

Important, then, are organizational issues and recommendations developed by this Commission. The increasing responsibilities for management functions implied in the foregoing sections will be vested in the organization or organizations the

Commission sees as the best option. It is important that this role be clearly recognized.

Although the proposed program set forth in the foregoing is not applicable to the Outer Continental Shelf the National policies and guidelines set forth in earlier sections of this chapter appear equally valid on the shelf as within the territorial sea.

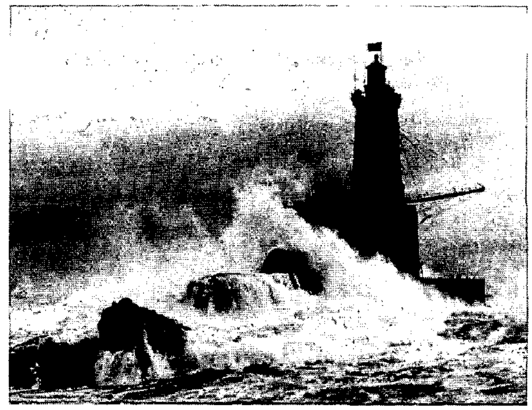

Figure 2. *Our Nation and the sea meet at the coastal zone. Sound management must be built upon a strong foundation responsible to and serving the public. (Coast Guard photo).*

The work of the panel was divided roughly into three general phases: (1) factfinding, (2) consultation and review, and (3) preparation of the report:

I. FACTFINDING

The gathering of facts and information was a vital part of the work of the panel. It consisted of informal hearings with leading representatives of Federal and State agencies, academic institutions and industry, and correspondence and interviews with other key individuals. Following are the schedule of hearings and the names of many who gave of their time and effort to assist the Panel in its work.

A. Schedule of Panel Hearings

Date	*City*	*Host*
Oct. 9-12, 1967	Washington, D.C.	
Nov. 6-7, 1967	Boston	Massachusetts Institute of Technology
Nov. 8-9, 1967	New York	Ford Foundation
Dec. 4, 1967	Chicago	Federal Water Pollution Control Administration
Dec. 5-6, 1967	Seattle	University of Washington
Dec. 7-8, 1967	La Jolla	Scripps Institution of Oceanography
Jan. 10-11, 1968	Houston	Gulf Universities Research Corporation
Jan. 12-13, 1968	Miami	University of Miami

B. Persons Appearing at Panel Hearings

Elbert Ahlstrom, Senior Scientist, Bureau of Commercial Fisheries, Ocean Research Laboratory, Stanford, California

Dick Bader, Associate Director, Institute of Marine Science, University of Miami, Miami, Florida

L. Bajorunas, Director, Great Lakes Research Center, Detroit, Michigan

George F. Beardsley, Jr., Assistant Professor, Physical Oceanography, Oregon State University, Corvallis, Oregon

Harry J. Bennett, Professor of Zoology, Louisiana State University, Baton Rouge, Louisiana

Leo Beranek, President, Bolt, Beranek & Newman, Cambridge, Massachusetts

Donald E. Bevan, Associate Dean, College of Fisheries, University of Washington, Seattle, Washington

F. G. Blake, Senior Research Scientist, Chevron Research Co., La Habra, California

C. Bookhout, Director, Duke University Marine Laboratory, Beaufort, North Carolina

Capt. J.D.W. Borop, USN, Director, U.S. Navy Mine Defense Laboratory, Panama City, Florida

Ronald A. Breslow, Executive Assistant to Commissioner, New Jersey State Department of Conservation and Economic Development, Trenton, New Jersey

Douglas L. Brooks, President, Travelers Research Center, Hartford, Connecticut

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Frank J. Schwartz, Research Professor, Chesapeake Biological Laboratory, University of Maryland, Solomons, Maryland
Thomas G. Scott, Head, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon
J. W. Selden, Division Vice President, New Products Commercial Development, St. Paul, Minnesota
Allyn H. Seymour, Director, Laboratory of Radiation Ecology, University of Washington, Seattle, Washington
David H. Shonting, Research Oceanographer, Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island
W. E. Shoupp, Vice President, Research, Westinghouse Electric Corporation, Pittsburgh, Pennsylvania
Carl N. Shuster, Jr., Director, Public Health Service, Northeast Marine Health Sciences Laboratory, Department of Health, Education and Welfare, Narragansett, Rhode Island
Bob Simpson, Fishing Editor, Yacht "Silver Spray," Morehead City, North Carolina
J. R. Singleton, Executive Director, Parks and Wildlife Department, Austin, Texas
G. Fred Somers, Chairman, Department of Biological Sciences, University of Delaware, Newark, Delaware
Jerome Spar, Professor of Meteorology, New York University, University Heights, New York
H. Burr Steinbach, Chairman, Department of Zoology, University of Chicago, Chicago, Illinois
Edward C. Stephan, Chairman, Oceanographic Committee of the Nassau-Suffolk Regional Planning Board, Hauppauge, New York
Dan E. Stewart, Director, Department of Conservation and Development, Raleigh, North Carolina
Harris B. Stewart, Jr., Director, Institute for Oceanography, Environmental Science Services Administration, Department of Commerce, Miami, Florida
James E. Sykes, Director, Biological Laboratory, Fish and Wildlife Service, Bureau of Commercial Fisheries, Department of the Interior, St. Petersburg Beach, Florida
Gerald B. Talbot, Director, Tiburon Marine Laboratory, Bureau of Sport Fisheries and Wildlife, Belvedere-Tiburon, California
John H. Terry, Director, Office of Naval Research, Department of the Navy, Boston, Massachusetts
Russell E. Train, President, The Conservation Foundation, Washington, D.C.
W. L. Turner, North Carolina State University, Raleigh, North Carolina
Albert Tyler, Chairman, Marine Station Committee, Professor of Biology, California Institute of Technology, Pasadena, California
David Wallace, Director, Fish and Game Division, New York Conservation Department, Ronkonkoma, New York
I. E. Wallen, Head, Office of Oceanography and Limnology, Smithsonian Institution, Washington, D.C.
Dale Wallington, Deputy Commissioner, Department of Natural Resources, Alaska
D. M. White, Alaskan Sea Frontier, Seventeenth Naval District, Alaska
Ralph R. Widner, Executive Director, Appalachian Regional Commission, Washington, D.C.
Charles E. Wilde, Jr., Director, The Mount Desert Island Biological Laboratory, Salisbury Cove, Maine
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James J. B. Worth, Head, Environmental Sciences Group Research Triangle Institute, Research Triangle Park, North Carolina
John M. Ziegler, Professor of Marine Geology, Department of Marine Sciences, University of Puerto Rico, Mayaguez, Puerto Rico

II. CONSULTATION AND REVIEW

The panel held monthly meetings incident to Commission meetings and in conjunction with the Hearings. Important in this phase of the work were the many inputs and views of consultants, reviewers, and others who provided material for use by the panel. It was not possible, of course, to incorporate the specific views of all consultants into the findings and recommendations of the panel. However, without the expert advice and constructive criticism of the following persons the work of the panel could not have proceeded.

Consultants and Reviewers

Joseph E. Bodovitz, Executive Director, San Francisco Bay Conservation and Development Commission
Joseph M. Caldwell, Acting Director, U.S. Army Coastal Engineering Research Center
Francis T. Christy Jr., Resources for the Future, Inc., Washington, D.C.
Sidney R. Galler, Assistant Secretary (Science), Smithsonian Institution
Eugene T. Jensen, Chief, Office of Estuarine Studies, Federal Water Pollution Control Administration
Boyd Ladd, Staff Liaison, National Council on Marine Resources and Engineering Development
James T. McBroom, Executive Secretary, Committee on Multiple Use of the Coastal Zone, Washington, D.C.
W. V. McGuinness Jr., Corps of Engineers, U.S. Army
James B. Meanor Jr., Executive Director of Civil Works, Corps of Engineers, U.S. Army
Alfred A. Porro, Jr., Attorney, Lyndhurst, New Jersey
Donald W. Pritchard, Director, Chesapeake Bay Institute, Johns Hopkins University
Lyle S. St. Amant, Assistant Director, Louisiana Wild Life and Fisheries Commission
S. Fred Singer, Deputy Assistant Secretary of the Interior for Water Pollution Control
Karl K. Terekian, Department of Geology, Yale University
Leon W. Weinberger, Assistant Commissioner for Research and Development, Federal Water Pollution Control Administration

In addition to the above, Commissioner David A. Adams, although not a member of the panel, participated fully in the work of the panel, for which the panel is deeply grateful.

III. PREPARATION OF THE REPORT

The preparation of this report, including the opinions, findings, and recommendations are wholly the responsibility of the panel Commissioners. However, the vast amount of effort in assembling data and presenting them is the work of many persons.

Much of the information on uses of and changes in the coastal zone (Chapters 2 and 3) was generously provided by John M. Clark, of the American Littoral Society; Joseph M. Caldwell, U.S. Army Coastal Engineering Research Center; and L. Eugene Cronin, of the University of Maryland.

Chapter 4 on pollution was compiled by panel staff associates, Captain Merlyn E. Natto, U.S. Environmental Science Services Administration; and William S. Beller, Department of the Interior.

Chapter 5, "Port Development and Redevelopment," was adapted from a U.S. Army Corps of Engineers Report of the same name through the courtesy of Brig. General Harry G. Woodbury, Director of Civil Works.

Chapter 6, on basic science, represents the combined efforts of many, including John Lyman, of the University of North Carolina; Joseph M. Caldwell; and William I. Aron, Smithsonian Institution.

Chapter 7, the activities of Federal agencies, came from material furnished by the agencies themselves and from the National Council on Marine Resources and Engineering Development. Activities of States was generously provided by Milton S. Heath, Jr., Institute of Government, University of North Carolina.

Chapter 8, on developing law, was prepared by H. Crane Miller, Smithsonian Institution. The work of Albert H. Garretson and Ludwik A. Teclaff, of New York University-Fordham University Marine Environment Legal Research Project, and of I. Michael Heyman, of the University of California at Berkeley, is particularly acknowledged.

The remainder of the report was compiled by staff associate Captain R. P. Dinsmore, U.S. Coast Guard.

NUMBERING DATA BY STATE

State	Total Boats Numbered 1966	Total Boats Numbered 1967	Approved numbering system	Laws compatible with Federal in equipment and operation	Scope of Current Boat Numbering System
Total	4,067,371	4,458,893			
Alabama	95,116	103,138	Yes	No	All motorboats, sailboats, and rental boats
Alaska	14,649	14,494	No	No	Motorboats of more than 10 horsepower
Arizona	27,331	32,941	Yes	No	All watercraft
Arkansas	29,390	27,858	Yes	No	Motorboats of more than 10 horsepower
California	316,525	374,975	Yes	Yes	All motorboats; and sailboats over 8 feet in length
Colorado	19,341	21,396	Yes	Yes	All motorboats and sailboats
Connecticut	59,125	64,705	Yes	Yes	Motorboats of more than 5 horsepower
Delaware	10,818	12,003	Yes	Yes	All motorboats
District of Columbia	2,764	3,016	No	No	Motorboats of more than 10 horsepower
Florida	163,089	179,308	Yes	Yes	Motorboats of 10 horsepower or more
Georgia	65,906	84,786	Yes	Yes	Motorboats of more than 10 horsepower
Hawaii	6,153	6,506	Yes	Yes	All motorboats; and sailboats over 8 feet in length
Idaho	33,950	37,819	Yes	Yes	All motorboats
Illinois	155,195	165,228	Yes	Yes	All motorboats; and sailboats over 12 feet in length
Indiana	133,517	133,265	Yes	No	All motorboats
Iowa	72,188	83,870	Yes	Yes	All motorboats
Kansas	25,884	27,811	Yes	No	Motorboats of 10 horsepower or more
Kentucky	51,309	55,110	Yes	Yes	All motorboats
Louisiana	72,618	78,975	Yes	No	Motorboats of more than 10 horsepower
Maine	38,602	40,703	Yes	No	Motorboats of more than 10 horsepower
Maryland	61,565	65,841	Yes	Yes	Motorboats of more than 7½ hp; and sailboats over 25 feet
Massachusetts	88,049	94,674	Yes	Yes	Motorboats of 5 horsepower or more
Michigan	270,335	385,124	Yes	(?)	All motorboats
Minnesota	253,014	252,795	Yes	Yes	All watercraft (with exceptions)[1]
Mississippi	15,138	17,585	Yes	No	Motorboats of more than 10 horsepower
Missouri	59,612	65,973	Yes	No	Motorboats of more than 10 horsepower
Montana	13,912	13,389	Yes	Yes	Motorboats of more than 10 horsepower
Nebraska	22,405	23,434	Yes	Yes	All motorboats
Nevada	11,149	11,016	Yes	Yes	All motorboats
New Hampshire	4,639	5,295	No	Yes	Motorboats of more than 10 horsepower
New Jersey	126,215	130,684	Yes	Yes	All motorboats
New Mexico	12,029	13,815	Yes	No	All motorboats and sailboats
New York	405,107	409,731	Yes	Yes	All motorboats
North Carolina	73,739	81,419	Yes	No	Motorboats of more than 10 horsepower
North Dakota	7,167	9,068	Yes	No	Motorboats of 10 horsepower or more
Ohio	168,921	177,458	Yes	(?)	All watercraft
Oklahoma	90,334	96,088	Yes	Yes	All motorboats
Oregon	68,054	72,032	Yes	Yes	Motorboats of more than 3½ hp; and sailboats 12' and over
Pennsylvania	114,293	108,078	Yes	Yes	All motorboats
Rhode Island	18,612	11,182	Yes	Yes	All motorboats
South Carolina	56,033	59,872	Yes	(?)	Motorboats of 10 horsepower or more
South Dakota	12,910	10,373	Yes	Yes	Motorboats of more than 6 horsepower
Tennessee	81,897	90,868	Yes	Yes	Motorboats of more than 10 horsepower

Recreational Boating Data (Cont'd)

NUMBERING DATA BY STATE

State	Total Boats Numbered 1966	Total Boats Numbered 1967	Approved numbering system	Laws compatible with Federal in equipment and operation	Scope of Current Boat Numbering System
Total	4,067,371	4,458,893			
Texas	197,993	223,082	Yes	Yes	All motorboats over 10 horsepower, regardless of length, and all motorboats over 14' in length, regardless of horsepower
Utah	19,084	20,298	Yes	Yes	All motorboats
Vermont	19,263	20,792	Yes	Yes	All motorboats
Virginia	54,364	58,602	Yes	Yes	Motorboats of 10 horsepower or more
Washington	85,881	87,614	No	No	Motorboats of more than 10 horsepower
West Virginia	10,855	11,222	Yes	Yes	Motorboats of more than 5 horsepower
Wisconsin	241,388	273,150	Yes	Yes	All motorboats; and sailboats 12 feet in length
Wyoming	5,669	6,416	Yes	Yes	Motorboats of more than 5 horsepower
Guam	211	228			Motorboats of more than 10 horsepower
Puerto Rico	3,208	1,879	Yes	Yes	All motorboats
Virgin Islands	1,010	1,909	Yes	Yes	All motorboats

Harbors	Authorized Depth[1]	Major Relocations and Dislocations[2]	Rock and/or Continental Shelf[3]	Spoil Disposal[4]	Ecology
	(Beginning depth of problem—in feet)				
ATLANTIC COAST					
NEW ENGLAND					
Bridgeport Harbor	35		60		
New Haven Harbor	35		40		
New London Harbor	33		60		
Portland Harbor	45	40	60		
Portsmouth Harbor and Piscataqua River	35	45-50	35		
Searsport Harbor	35		60		
Boston Harbor	40	35-50	60		
Cape Cod Canal	32	40-45	40		
Dorchester Bay and Neponset River	35		60		
Mystic River	35	45	40		
Salem Harbor	32		60		
Weymouth-Fore and Town Rivers	35	45-50	40		
Providence River and Harbor	40		55		
Fall River Harbor	30	45	60		
New Bedford and Fairhaven Harbor	30	40	35		
NORTH ATLANTIC					
New York Harbor	45				
Newark Bay, Hackensack and Passaic Rivers	35	35	30-35		
New York and New Jersey Channels	35	45	38		
East River	40		35		
Delaware River, Philadelphia to the Sea	40		41-65	41	40-51[5]
Delaware River, Philadelphia to Trenton	40	50	41	41	40[5]
Wilmington Harbor	35			36	35-40[5]
Baltimore Harbor	42	60	50	44	50[5]
York River Entrance Channel	37	60		45	
Thimble Shoal Channel	45	55			
Norfolk Harbor	35-45	35-55		45	
Channel to Newport News	45	55		45	

Major Obstacles to Harbor Deepening (Cont'd)

Harbors	Authorized Depth[1]	Major Relocations and Dislocations[2]	Rock and/or Continental Shelf[3]	Spoil Disposal[4]	Ecology
	(Beginning depth of problem—in feet)				
SOUTH ATLANTIC					
Morehead City Harbor	35	50-60	50-100	50	35[6] & 60-90[5]
Wilmington Harbor	38	50-60	38-45	50	38[6] & 50-60[5]
Charleston Harbor	35		40		
Savannah Harbor	38	44			
Brunswick Harbor	30		32		
Fernandina Harbor	28-32	34		65	
Jacksonville Harbor	42	42-48	44	42	
Canaveral Harbor	37	37-43		37	
Palm Beach Harbor	35	35-41	37	35	45[6]
Port Everglades Harbor	40	40-46	42	40	
Miami Harbor	30	30-36	32	30	
Key West Harbor	30	30-36	32	30	
GULF COAST					
Charlotte Harbor	32	32-38		32	
Tampa Harbor	36	36-42	38	36	
Mobile Harbor	42	45		45	
Panama City Harbor	34	45		40	
Pensacola Harbor	35			35	40[6]
Port St. Joe Harbor	37			45	
Pascagoula Harbor	38	45-50		45	
Gulfport Harbor	30	50		40	
Mississippi River-Gulf Outlet	36			36	
Mississippi River, Baton Rouge to Gulf of Mexico	40			40	
Calcasieu River and Pass	40	40		40	
Galveston Harbor	40-42		52		
Galveston Channel	36			45	
Houston Ship Channel	40	45-50		45	
Port Aransas-Corpus Christi Waterway	40-42	50			
Sabine-Neches Waterway	40-42	50	47		40[5]
Freeport Harbor	36-38	38			
Houston Ship Channel Greens Bayou	36	36-50		45	
Texas City Channel	40		52		

Major Obstacles to Harbor Deepening (Cont'd)

Harbors	Authorized Depth[1]	Major Relocations and Dislocations[2]	Rock and/or Continental Shelf[3]	Spoil Disposal[4]	Ecology
	(Beginning depth of problem—in feet)				
PACIFIC COAST					
Columbia River Entrance	48	48		48	48[5,6]
Columbia and Lower Willamette Rivers	40	40-45	40	40	40[5,6]
Coos Bay	30-40	40	30-40	35	40[5,6]
Yaquina Bay	30-40	40	20-40	30-40	40[5,6]
Skipanon Channel	30	35	50	35	
Puget Sound Harbors (Bellingham, Anacortes, Everett, Seattle, Tacoma, Olympia and Port Angeles	Depths in Puget Sound range from 200-900 feet. No serious obstacles to deepening appear to be forthcoming.				
Grays Harbor	30	45	30	45	30[5] & 45[6]
San Francisco Harbor	35-55	100	200-300	35-55	
Richmond Harbor	30-45	30-85	36-300	30-45	
San Pablo Bay and Mare Island Straits	30-45	45-50	100-150	30-45	
Oakland Harbor	35	35-100	300	35	
Redwood City Harbor	30	35-100	150-300	30	
Humboldt Harbor and Bay	26-40	26-30			
San Francisco Bay to Stockton	35-45			40-50	35[5] & 40-50[6]
Sacramento River	30				35[6]
Los Angeles-Long Beach	35-40	40-55			
San Diego Harbor	20-40	35-50			
GREAT LAKES					
Two Harbors	28		28		
Silver Bay	30		30		
Taconite Harbor	30		30		
Milwaukee Harbor	27		40		27[7] & 40[5]
Chicago Harbor	28		40	28	28[7] & 40[5]
Calumet Harbor	27	40			27[7] & 40[5]
Indiana Harbor	27	30	40	30	27[7] & 40[5]
Burns Waterway Harbor	27		40		40[5]
Buffington Harbor	26		40	26	26[7] & 40[5]

Major Obstacles to Harbor Deepening (Cont'd)

Harbors	Authorized Depth[1]	Major Relocations and Dislocations[2]	Rock and/or Continental Shelf[3]	Spoil Disposal[4]	Ecology
	(Beginning depth of problem—in feet)				
Escanaba Harbor	29				29[7] & 40[5]
Gary Harbor	27		40	27	27[7] & 40[5]
Sandusky Harbor	24		24		
Lorain Harbor	27	27	27	27	27[7]
Cleveland Harbor	27			27	27[7]
Ashtabula Harbor	27		27		
Conneaut Harbor	27		27		
Erie Harbor	27		27		
Buffalo Harbor	28		27	23	28[7]
Huron Harbor	28	28			
Detroit River	27	27	27		
St. Clair River	27	40	40		
Straits of Mackinac	30		27		
Toledo Harbor	27		50		
St. Mary's River	27	27	27		
Trenton Channel, Detroit River	27		27		
Saginaw River	25		80		
Muskegon Harbor	27		80		

[1] Authorized depth is the channel depth in feet to which harbor deepening has been authorized by law. It is not necessarily the actual or controlling depth which presently exists.

[2] Relocations and dislocations are the depths which channels would affect existing shorelines, wharves, or other installations. See Section VII-C of Chapter 5.

[3] This is the depth at which bedrock or other heavy material underlying the softer sedimentary overburden is reached. The cost of dredging beyond this depth becomes substantially greater.

[4] This depth in feet shows the channel depth at which the disposition of dredge spoil becomes a significant problem. See Section VI-E of Chapter 5.

[5] Damage to water supplies, either by salt water intrusion or damage to aquifers.

[6] Includes loss of fish and wildlife habitat, destruction of unique geological areas or plant life, etc.

[7] Pollution problem.

Source: U.S. Army, Corps of Engineers, Office of Civil Works.

Alabama *Regulation* Alabama authorizes its State Docks Authority to establish "harbor lines." When such lines are established, the Docks Authority has supervision and control over all activities landward of the harbor lines. In the absence of harbor lines, the Department of Conservation exercises similar authority over the area below mean high tide. State ownership of the area below mean high tide is said to be "well established." Because of its very limited estuarine areas, the State is seeking to preserve all the existing areas. Responsibility for regulation is divided between the State Department of Conservation–which includes Divisions of Administration, Forestry, Game and Fish, Seafoods, State Lands, State Parks and Water Safety–and the State Docks Authority. The Department of Conservation is authorized to acquire lands (including estuarine areas) in connection with its fish and game programs.

Funding Total State program spending for protection, conservation, and research activities is approximately $300,000 annually.

Court Tests State ownership of areas below mean high tide is reported to be "well established." Apparently there have been no court tests concerning validity of regulatory legislation.

Coordination Internal coordination of State programs affecting estuaries is carried out between the Conservation Department and the Docks Authority. Both of these agencies coordinate with the Corps of Engineers and the Department of Interior on Federal-State matters, including Corps permits for projects affecting navigable waters. The Governor's office coordinates the efforts of the State's industrial development agencies with the State's conservation programs.

California (1) California is in the midst of an extensive planning program for estuarine conservation in one area, the San Francisco Bay, begun with enactment of a legislative framework in 1965 and scheduled for completion in 1969. The planning agency, the San Francisco Bay Conservation and Development Commission, was directed to: study the bay, prepare a comprehensive conservation and development plan for the bay and its shoreline, and (as an interim measure) to protect the bay during the planning period by controlling dredging and filling by permits during the planning period. Through 1966 the Commission had issued 25 interim permits, denied 5 permits.

Presently about 50 per cent of the San Francisco Bay is State owned, 20 per cent city or county owned, 5 per cent Federally owned, and 25 per cent privately owned.

This study commission has projected 23 separate staff or consultant reports dealing with the bay as a resource, predicted future development, planning for transportation and for land and water use, and plan implementation. The annual Commission budget has been substantial, e.g., $243,924 in fiscal year 1967. The initial studies have been completed, but the Commission is finding that the final report dealing with funding and powers to implement its estuarine plan is taking longer than anticipated.

(2) A similar planning process has been proposed for the Humboldt Bay area in California.

(3) The San Francisco Bay Commission, in April 1968, published a comprehensive 7-volume report on Powers and Money Needed to Carry Out the Bay Plan. (A summary pamphlet version is also available.) This report reviews in detail the alternatives available to the area for controlling bay filling activities and for planning, administering, and financing a program. The report provides an excellent source of information in depth for other States and areas. It includes a useful analysis of the pros and cons of the various revenue and organizational options and an extensive review of the legal precedents bearing upon regulation of estuarine land use.

[1]This material was obtained largely from Milton S. Heath, Jr.; Associate Director, Institute of Government, University of North Carolina, and from George P. Spinner of the Marine Resources Committee, State of North Carolina. Additional information on State activities can be found in a contract report of the Commission, *A Perspective of Regional and State Marine Environmental Activities,* by John I. Thompson & Co., Feb. 29, 1968, available from Clearinghouse for Federal Scientific and Technical Information, Department of Commerce, Springfield, Virginia 22151, P.B. No. 177765.

Connecticut *Regulation* The removal of sand and gravel from lands under tidal and coastal waters and the erection of structures and works in tidal, coastal, and navigable waters are regulated by the Connecticut Water Resources Commission. This affords some control over dredge and fill projects, but the State has no jurisdiction over filling tidal marsh from inland by means of dump trucks and bulldozers.

Acquisition The State of Connecticut claims title to all lands below mean high water. However, no demarcation lines have been established, and over the years private interests have reportedly exercised claims including most of the tidal marshes.

The Connecticut Board of Fisheries and Game is authorized to acquire tidal marsh by gift, lease, purchase, or condemnation. Reportedly, the State has lost about half of its tidal marshes since 1914. Of some 14,800 acres that remain, the Board of Fisheries and Game owns about 4,200 acres and hopes to acquire another 7,000 in the next few years. The Board is recommending acquisition of the remaining 3,600 acres by private conservation agencies or municipalities. A wetlands committee has been organized by private conservation groups, and the U.S. Bureau of Sports Fisheries and Wildlife is studying the establishment of a National Wildlife Refuge.

Agency As indicated above, acquisition of tidal marsh is primarily performed by the Board of Fisheries and Game, while regulatory powers are vested in the Water Resources Commission.

Funding Spending for tidal marsh acquisition by the Board of Fisheries and Game during this biennium is expected to total about $500,000.

Court Tests None, other than litigation concerning common law ownership rights.

Coordination At the State level, coordination of conservation and development activities in estuaries is carried out by the State Development Commission and the State Highway Department on behalf of development, and by the Department of Agriculture and Natural Resources, the Park and Forest Commission, the Board of Fisheries and Game, and the Water Resources Commission on behalf of conservation. A comprehensive State plan for development has been prepared by these agencies and is coordinated with local and regional plans.

Delaware *Regulation* The Delaware State Planning Office has reflected on its Comprehensive Plan Map a substantial portion of Delaware's coastal wetlands for conservation purposes. This action has reportedly been used as a weapon in resisting minor subdivision development, but its ability to restrain major developmental encroachments has apparently not been tested. The State Planning Office has recommended that some kind of State zoning be provided to implement this open space proposal, but no zoning has yet been adopted.

Acquisition State land acquisition for estuarine protection is authorized, apparently through the State Board of Game and Fish Commissioners. State, Federal, and private conservation groups reportedly own about 60,000 acres of coastal salt marsh and expect to acquire another 10,000 acres. The remaining 40,000 acres of salt marsh is said to be largely owned by oil and chemical companies.

Agency The Board of Game and Fish Commissioners is responsible for conservation of estuaries and expresses its views on proposed developments in hearings before the State Water and Air Resources Commission or the State Planning Division.

Funding Funding of State programs for conservation and protection of estuaries in recent years has ranged from $50,000 to $300,000 annually.

Court Tests None.

Coordination The Board of Game and Fish Commissioners, the Water and Air Resources Commission, and the State Planning Division coordinate with one another their respective programs affecting estuaries.

Florida *Regulation* Florida authorizes the designation of a "bulkhead line" along or offshore from tidal lands. Beyond such a bulkhead line no filling or bulkheading is allowed; in one county (Manatee) in addition no dredging is allowed beyond the bulkhead line.

Acquisition The salt marsh in the NASA complex at Cape Kennedy, about 40,000 acres, has been set aside in a National Wildlife Refuge.

Agency Bulkhead lines are fixed by the local city or county governing body, subject to the approval of the Trustees of the Internal Trust Fund (composed of the Governor and six State cabinet officers). A preliminary biological, ecological, and hydrological study is required from the State Board of Conservation. In this connection the Board of Conservation has issued a circular containing guides for evaluating marine productivity and adopting standards for waterfront development. The Trustees of the Internal Fund have reportedly placed a moratorium on dredging and filling until these studies can be completed.

Georgia *Regulation and Acquisition* Other than the usual fish and game regulations and water pollution controls, Georgia apparently has no current active program for regulation or acquisition of estuarine areas. However, the power to acquire land is vested in the Game and Fish Commission for waterfowl areas and in the State parks agency for public parks.

Agency The State Game and Fish Commission is responsible for wildlife and fishery programs, including marine as well as inland fisheries. The Water Quality Control Board is responsible for water pollution control in estuaries and elsewhere in the State.

Funding No information.

Court Tests None.

Coordination It is reported that the State Planning Bureau and the Coastal Area Planning Commission will probably eventually serve to coordinate conservation and developmental matters.

Louisiana *Regulation* Other than general water pollution control legislation, Louisiana's only regulatory controls protecting estuaries are based on permits issued by the Corps of Engineers or by Louisiana's Mineral Board or Department of Public Works, involving publicly owned bottoms.

Agency The permits for projects affecting publicly owned bottoms are not granted without prior examination and approval of the Wild Life and Fisheries Commission.

Funding Total State program spending for estuarine research, management, and development is about $1 million annually.

Court Tests Only legal tests have apparently involved State ownership of bottoms, not validity of regulatory legislation. State control of bottoms has reportedly been upheld except in rare cases involving Spanish land grants.

Coordination Conservation activities of Wild Life and Fisheries Commission are coordinated with Corps of Engineers, U.S. Geological Survey, Fish and Wildlife Service, and State Mineral Board, Department of Conservation and Board of Health.

Maine *Regulation* Other than general water pollution control and pesticide control legislation, Maine's principal regulatory controls for estuarine protection involve: (1) a 1967 coastal wetlands alteration permit law and (2) Corps of Engineers permits for alteration of coastal wetlands. The 1967 wetland control law prohibits filling, removing, dredging, or draining of sanitary sewage into wetlands bordering coastal waters without a permit from the municipality (or county) affected, issued with the approval of the Wetlands Control Board. Approval may be withheld if the proposal threatens public health, safety, or welfare; would adversely affect abutting owners; or would damage conservation of water supplies or wildlife or fisheries.

Acquisition Both the Inland Fisheries and Game Department and the State Park Commission have current coastal land acquisition programs. The U.S. Bureau of Sports Fisheries and Wildlife is acquiring about 4,000 acres of salt marsh as National Wildlife Refuge Areas.

Agency The Wetlands Control Board consists of the Commissioner of Sea and Shore Fisheries, the Commissioner of Inland Fisheries and Game, the Forest Commissioner, the Chairman of the Highway Commission, and the Chairman of the Water Improvement Commission. The Department of Sea and

Shore Fisheries has general responsibility for coastal fisheries. Land acquisition is a function of the Inland Fisheries and Game Department (for waterfowl) and the State Park Commission for recreational park purposes.

Funding Wetland acquisition for water fowl purposes is proceeding at about $20,000 annually. Twenty-two miles of waterfront valued at $3 million are owned by the State Park Commission, and another $2 million in bond issues is pending.

Court Test The wetland acquisition program has apparently been sustained in court.

Coordination of Regulation and Development Some coordination may be achieved by the Interdepartmental Task Force or Water and Related Land Resources.

Maryland *Regulation* Other than general water pollution control legislation and local zoning controls, the protection of estuaries in Maryland is apparently provided through controls over State owned lands.

Acquisition Lands bordering estuaries are acquired by the Department of Game and Inland Fish and the Department of Forests and Parks (both under a Board of Natural Resources).

Agency Controls over State owned lands are delegated to the Board of Public Works on recommendations of the Department of Chesapeake Bay Affairs, the Department of Water Resources, the Department of Game and Inland Fish, and the Department of Forests and Parks. Acquisition is by the Department of Game and Inland Fish or the Department of Forests and Parks.

Planning An extensive planning study of all wetlands, including estuaries, is underway.

Court Tests The State's control over taking of sand and gravel from the Potomac has been sustained in court.

Coordination Coordination of conservation, development, and navigation is by the Board of Natural Resources, meeting with the Director of Economic Development and Planning Department representatives.

Massachusetts *Regulation* Other than water pollution control legislation, Massachusetts principal regulatory controls for estuaries consist of: (1) a statute prohibiting the removing, filling, or dredging of any bank, flat, marsh, meadow, or swamp bordering on coastal waters, without specified local and State permission or restrictions and (2) a related statute authorizing a "rule making" approach, under which the Commissioner of Natural Resources with the approval of the Board of Natural Resources may adopt regulations concerning alteration or pollution of coastal wetlands; if these regulations are found in court to constitute a "taking" of property, the Department may proceed to condemn the land in fee or lesser interest by eminent domain. This legislation was enacted after extensive studies and reports. The Department of Natural Resources regards the rule-making authority as the more promising approach. It permits the Department to move on a regional basis to preserve wetlands without waiting for actual development commitments. Under this law, for example, the Department recently established a wetlands protective area covering 35,000 acres in one town.

Agency The Department of Natural Resources administers the program through several of its divisions.

Program Goals Program goals being carried out through a series of estuarine studies are to maintain the estuaries in as near as possible to present conditions consistent with management programs.

Funding Estuarine research is currently supported at about $120,000.

Court Tests The Massachusetts wetlands permit legislation has been sustained in lower court tests, but the rule-making authority has apparently not yet been litigated.

Coordination The conservation efforts are coordinated by the Department of Natural Resources with the State Department of Public Works, the State Division of Water Pollution Control, the U.S. Corps of Engineers, Bureau of Commercial Fisheries, and Bureau of Sports Fisheries.

Mississippi *Regulation and Acquisition* Mississippi apparently has no current program for regulation or acquisition of estuarine areas other than through participation in Corps of Engineers navigation permit proceedings.

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Agency The Gulf Coast Research Laboratory is responsible for research and the Mississippi Marine Conservation Commission for leasing of offshore bottoms and other estuarine conservation.

Funding The annual expenditures of the above two agencies is about $500,000, over 75 per cent for research.

Court Tests None.

Problems Only problems noted resulting from development are spoil deposits.

New Hampshire *Regulation* New Hampshire adopted in 1967 a statute prohibiting the removal, excavation, filling, or dredging of any bank, flat, marsh, or swamp in and adjacent to tidal waters without the approval of the New Hampshire Port Authority. Conditions to protect fish and game may be prescribed by the State Fish and Game Department, and installation of bulkheads or other structures may be prescribed by the Port Authority. Two other 1967 laws prohibit dredging any marsh or swamp lying below the mean high water level of any public waters or filling below mean high water level of public waters without approval by the Governor and Council.

Acquisition Tidal marshes are being acquired by the State Fish and Game Department in small installments, by gift or as funds become available. Progress has been slow, but the Department in cooperation with private groups is now seeking to raise funds to acquire one 4,500 acre marsh. It is thought that condemnation powers may be required to clear some titles.

Agency The Port Authority is vested with principal regulatory authority under the tidal lands control law. The Fish and Game Department is generally reponsible for fish and wildlife conservation, including marine fisheries, and has estuarine land acquisition authority.

Funding Estuarine land acquisition is currently hampered by lack of State funds, procedures, and personnel, but Federal aid is available for acquisition.

Court Tests None.

New Jersey *Acquisition* A large-scale estuarine acquisition effort is underway in New Jersey. Passage of a $60 million Green Acres bond issue in 1964 has reportedly resulted in acquisition of about 20,000 acres of salt marsh by the Division of Fish and Game, and another 50,000 acres are being acquired. Previously, the Division had acquired about 30,000 acres. The U.S. Bureau of Sport Fisheries expects to control over 50,000 acres when its acquisition plans are completed. Upon completion of all of these programs, about 90 per cent of the high value coastal salt marsh of New Jersey is expected to be protected. Under the Green Acres program, total State and local land acquisition in the coastal counties has been about 65,000 acres. An additional 50,000 acres acquisition is projected in these counties under the program.

Regulation Other than the usual fish and game regulations, water pollution controls, and local zoning regulation, the protection of estuaries is apparently provided mainly through control over State owned lands.

Agency The State Department of Conservation and Economic Development is responsible for estuarine land acquisition and the State Department of Health for pollution control. Coordination of State estuarine programs largely involves these two agencies.

Funding Operating expenses for estuarine areas protection were $93,000 in 1967; projected 1968 operating expenses are $142,000. For capital expenses, see "Acquisition," above.

New York *Regulation and Acquisition* Other than the usual fish and game laws, water pollution controls, and restrictions upon the grant or lease of State lands, New York exercises no regulatory controls in estuarine areas. New York, however, does have a multi-faceted program for public land acquisition and for conservation of lands in public ownership.

Under the Park and Recreation Land Acquisition Bond Act of 1960, the State Conservation Department was authorized to purchase wetlands throughout the State, and did in fact acquire one tract of nearly 200 acres of tidal marsh. Under the Fish and Game Law the State may purchase land from any source, and under the Conservation Law the Water Resources Commission may take land by eminent domain.

The Long Island Wetlands Act permits the State government to enter cooperative agreements with the towns and counties on Land Island in support of conservation of tidal marshes. Where wetlands owned by towns or counties have been dedicated to conservation purposes, costs of maintenance and operations are shared by the State on a 50-50 basis with the local government. Cooperative agreements may also provide for development of dedicated wetlands by the State Conservation Department with its own personnel. Fifteen thousand five hundred acres of wetlands are now under cooperative agreements with the townships. Program goals are to extend the agreements to about 31,000 acres of remaining township lands, which constitute the bulk of significant Long Island wetlands.

Agency The State Conservation Department is primarily responsible for estuarine conservation programs. Condemnation powers are vested in the Water Resources Commission.

Funding Average annual State expenditures under the Long Island Wetlands Act are projected at about $15,000.

Court Tests None.

Coordination of Regulation and Development The Water Resources Commission is responsible for coordination of all activities centered on water.

North Carolina *Regulation* The broadest authority vested in any State agency in North Carolina is granted to the Department of Conservation and Development, acting primarily through its Division of Commercial and Sports Fisheries. General jurisdiction is granted to this Department over the conservation of marine and estuarine resources–which include coastal and ocean fish and fisheries, related plant and animal life, and the entire ecology supplying them. In addition to the Army Engineers permits, State legislation was proposed in 1967 in North Carolina which would have required permits for dredging and filling of coastal marshlands. The permit authorization was turned down by the General Assembly, however, and a compromise law was passed which merely requires registration of dredges, draglines, and other heavy equipment used in dredging and filling publicly owned tidelands and marshlands. This law is administered by the Department of Water and Air Resources. A riparian land owner may request an easement to fill submerged land fronting his property. The views of adjoining riparian land owners are solicited, and the effect of the proposed filling on navigable waters is evaluated. Any material dredged from State owned submerged lands to fill on private property is charged for at the rate of 25¢ per cubic yard for the first 1,000 cubic yards; 15¢ per cubic yard for the next 1,000; and 10¢ per cubic yard for any over 2,000 cubic yards.

The volume of requests for easements is not large, and more are denied than are granted. An effort is made to hold approvals down to small tracts. This appears consistent with efforts to protect the natural condition of estuarine areas.

Acquisition Comprehensive land acquisition powers to lease, purchase, and condemn estuarine lands in the best interests of conserving marine and estuarine resources are conferred on the Board of Conservation and Development. (The State Lands Act governs acquisition procedures, which are the responsibility of the Department of Administration with the approval of the Governor and Council of State. Other land acquisition powers that might be used in estuaries include the authority of the Board to acquire land for State forests and parks.)

Court Tests One test is in progress in connection with a proposed private waterfront improvement on a creek off the Atlantic Intracoastal Waterway near Wilmington. In this case the owner applied to the Army Engineers for a permit to dig a small navigation channel along the shore in front of his property. The State recommended denial of the permit on the grounds that public marsh would be destroyed; the area affected was relatively very small, but this stand was taken as a matter of principle and the permit was denied. The owner expressed willingness to create a spoil bank on the creek side of the channel, grade it to the proper elevation, and plant local marsh grass on it, to an extent that would provide more marsh than was destroyed. The matter is under investigation, as his proposal would appear to overcome State objections.

Coordination The State Planning Task Force of the Department of Administration is serving as coordinating agency for the State and with the three-State Coastal Plains Regional Commission (North Carolina, South Carolina, and Georgia). This program will serve in its region (which includes 45 North Carolina counties) as a focus for coordination of State resource and development programs. Its principal source of funds will probably be Federal moneys under the Public Works and Economic Development Act. In its work with local development projects and agencies in the coastal counties, the Coastal Plains Commission will undoubtedly play a role in coordinating development with estuarine management and conservation.

Oregon (1) Oregon is now engaged in an inventory and planning study of estuarine conservation under the Clean Waters Restoration Act from which answers are expected within a year. From this study, areas of conflict are expected to be defined and a single responsible agency to be designated.

(2) Present controls apparently involve only the usual water pollution control regulation, fisheries management, and public land controls.

Rhode Island *Regulation* Rhode Island in 1967 adopted an Intertidal Salt Marsh Law, which prohibits disturbing the ecology of intertidal salt marshes by dumping or excavating the marshes without a permit from the Department of Natural Resources. Current policy more or less prohibits any filling. Several applications to fill have been turned down, at least two dumps shut down, and a number of activities stopped.

Acquisition The State Natural Resources Department has made limited acquisitions of salt marshes and has planned a more extensive program when more funds are available. The Department does not have condemnation powers.

Agency The entire Rhode Island State program is carried on within the various divisions of the State Department of Natural Resources (Divisions of Harbors and Rivers, Conservation, Planning and Development, and Law).

Funding Limited funds have been made available periodically for salt marsh acquisition. The operating programs are carried on as part of the activities of existing divisions of the Department of Natural Resources without specific budgeting.

Court Tests No test of the Intertidal Salt Marsh Law has been made beyond the lower courts.

Coordination of Regulation and Development All coordination is apparently carried on internally within the relevant divisions of the Department of Natural Resources. Permits are issued by the Division of Harbors and Rivers, inspections made by the Division of Conservation, and enforcement conducted by the Division of Enforcement. When necessary, the Division of Planning and Development reviews applications.

South Carolina *Regulation and Acquisition* Other than the usual fish and game laws, water pollution controls, and procedures for the grant or lease of State lands, South Carolina has no regulatory controls in estuarine areas. No active estuarine acquisition program is now underway, but the Wildlife Resources Department has acquired several large salt marsh areas for waterfowl hunting. About 30,000 acres of salt marsh are included in the Cape Romaine National Wildlife Refuge. An estuarine study program is being initiated at about the time this publication is being issued.

Agency The South Carolina Wildlife Resources Department (including its Commercial Fisheries Division) appears to be the State agency with the principal current program interest affecting estuaries. The estuarine studies recently initiated are under the Water Resources Committee.

Funding No information available.

Court Tests As this publication goes to press, a test case is in progress before the State Supreme Court to determine if the State owns (as it claims) to the mean high water line or only to the mean low water line—whether the State owns its "tidelands."

Coordination of Regulation and Development The principal agencies that would be listed at this writing as likely to be involved in arrangements for coordinating estuarine regulation and development are the Division of Commercial Fisheries of the Department of Wildlife Resources, the Division of General Services of the Budget and Control Board, and the State Attorney General.

Texas *Regulation* Other than the usual water pollution control legislation, Texas' only regulatory controls over estuaries involve: (1) establishment of bulkhead lines over submerged State lands, beyond which leases may not be made and (2) authority to regulate disturbance of bay bottoms that might affect fish or shellfish nursery areas.

Program Goals To protect nursery areas, oyster reefs, and fish producing waters; a permit system to regulate disturbance of bay bottoms is now being designed.

Agency The Texas Parks and Wildlife Department is responsible for protection of bay bottoms. The Submerged Land Committee (composed of Director of Parks and Wildlife Department, two university marine science officials, and two Governor's appointees) advises the School Land Board on leases and bulkhead lines.

Court Tests Bay bottoms regulation has been confirmed by the Attorney General.

Funding The Department expects to have one full-time professional employee.

Virginia No detailed information was obtained from Virginia State agencies concerning estuarine programs. It is reported that the Commission of Game and Inland Fisheries, the Commission of Fisheries, the Water Control Board, and the Division of Water Resources all have administrative responsibilities relating to estuarine resources. It is also reported that the Commission of Game and Inland Fisheries has acquired several large areas of coastal marsh and expects to acquire more, that the State Parks Commission also has acquired some salt marsh, and that a feasibility study for further acquisitions is contemplated.

Washington The Department of Natural Resources controls ownership, disposal, and leasing of tidal and subtidal lands. The Department of Fisheries is responsible for the State's $6.5 million annual program of fisheries management and research, including shellfish and food fish.

The panel recommendations set forth in the Summary and in the text pose requirements for Federal funding to accomplish them.

The following tables summarize (1) funding for new programs specifically recommended by the panel and (2) funding for new programs proposed by Federal agencies coming under the general scope of panel endorsements. Duplicate funding is avoided except where cited.

Existing Federal funding is shown in Table 1 of Chapter 7.

Table E-1
NEW FUNDING ENVISIONED AS NECESSARY TO ACCOMPLISH RECOMMENDATIONS OF THE PANEL

The following table sets forth panel assessments of funding required to accomplish the specific recommendations by the panel. Basic recommendations are in the summary immediately preceding Chapter 1. References to text material are cited.

	$ millions First Year FY '70	Total Ten Year FY '70-'80
1. State Coastal Zone Authorities		
a. *Planning and Operations* (See Chapter 10, Section VI-B) This figure is developed on the basis of 30 State agencies, each having 4 professional and 12 technical personnel with average salaries of $12,000/year plus 100% overhead. This equals $10.9 million per year. Assume 50% Federal support for 2 years and uniform implementation over a 5-year period plus 15% administrative expenses.	2.5	12.5
b. *Enforcement Grants* (See Chapter 10, Section VI-C) Based on specific estimates provided by California, North Carolina, and Louisiana Authorities showing an average annual need of $100,000 per authority for enforcement purposes alone. 30 such Authorities aided by matching Federal Grants of 66-2/3% per year.	2.0	20.0
2. Coastlands Acquisition (See Chapter 10, Section VI-E)		
a. *Wetlands and Marshlands* (See Chapter 10, Section VI-E)	16.7	167.0

Table E-1 (Cont'd)

	\$ millions First Year FY '70	Total Ten Year FY '70-'80
b. *Public Access and Potential Recreation Areas* (See Chapter 10, Section VI-E)	8.3	83.0
3. Precise Shoreline Mapping (See Chapter 8, Section 1)	2.94	5.56
4. Coastal Zone Research		
a. *Institutional Support for Coastal Zone Labs* (See Chapter 9, Section III) This figure is developed on the basis of 30 coastal laboratories, each having 12,000 square feet and 20 person staff. The average annual operating and capital costs total about \$750,000. Federal share is 66-2/3%.	15.0	150.0
b. *Coastal Zone Research and Training* (See Chapter 9, Section III) This figure is based on existing Sea-Grant proposals and estimates	12.0	120.0
5. Coastal Inventory and Survey (See Chapter 9, Section II-A) Funds for this are being appropriated from existing agency programs	–	–
6. National Port Survey (See Chapter 9, Section II-C)	0.2	4.0
7. National Shoreline Erosion Survey (See Chapter 9, Section II-B) This survey has been authorized for accomplishment, but funds have not been appropriated.	0.3	1.0
8. Great Lakes Restoration Project (See Chapter 9, Section II-D)	1.0	30.0
9. Federal Grants for Waste Treatment Plants (See Chapter 4, Section IV) These funds amounting to a current backlog of about \$1.7 billion are a total National matter and not specifically coastal zone. (See Chapter 9, Section V)	–	–

Table E-1 (Cont'd)

	$ millions First Year FY '70	Total Ten Year FY '70-'80
10. Oil Pollution Research (See Chapter 9, Section I-B) This funding also has been proposed by Departments of the Interior and Transportation. (See Table E-2)	1.5	10.0
11. Improved Navigation System (See Chapter 9, Section I-B) This figure represents estimates by the Coast Guard for the implementation of LORAN B.	1.0	10.0
12. Water Quality Monitoring (See Chapter 6, Section V) These figures are based on FWPCA estimates to meet the needs for water quality monitoring networks in estuarine areas.	1.1	56.3
TOTAL NEW FUNDING	64.54	669.36

Table E-2
NEW FUNDING PROPOSED BY FEDERAL AGENCIES TO ACCOMPLISH PROGRAMS OR INITIATIVES RECOMMENDED OR INFERRED BY THE PANEL

The following table comprises Federal agency accessments of new initiatives for programs falling within the scope of recommendations of the Panel Report. These programs are described briefly in Chapter 7. Funding is based on information furnished to the National Council on Marine Resources and Engineering Development through the Committee on Multiple Use of the Coastal Zone. This funding is not specifically recommended or endorsed by the panel or the Commission. It does, however, represent funding either in whole or part which might be accomplished if recommendations of the panel are to be accomplished. Note that these programs and funding thereto are in addition to existing agency funding within the coastal zone, shown in Table 1 of Chapter 7.

	$ millions First Year FY-'70	Total Ten Year FY '70-'80
Department of the Interior		
Bureau of Commercial Fisheries		
a. Estuarine Research and Management	4.1	40.0
b. Aquaculture	5.3	50.0
c. Mapping Resources of the Continental Shelf	4.0	4.0

Table E-2 (Cont'd)

	$ millions First Year FY '70	Total Ten Year FY '70-'80
Federal Water Pollution Control Administration		
a. Combating Oils Spills[1]	0.5	5.0
Geological Survey		
a. Physical Facts of the Estuarine Environment	2.75	27.5
National Park Service		
a. Marine Underwater Observation and Interpretation	0.5	5.0
Bureau of Sports Fisheries and Wildlife		
a. Artificial Reefs	0.2	2.0
Department of Commerce		
Environmental Science Services Administration		
a. Seward Boundary Determination[2]	2.94	5.56
b. Circulatory Characteristics of Coastal Waters	2.47	4.0
Maritime Administration		
a. Seaport Control Tower	0.15	0.15
b. Offshore Ports	0.5	1.0
Department of Transportation		
Coast Guard		
a. Oil Pollution[3]	1.05	4.0
b. Port Advisory Services	0.2	2.0
c. Hazardous Cargo Information Center	0.25	2.5
Department of Health, Education and Welfare		
a. Finfish Sanitation	0.65	6.5
b. Toxic Chemical Pollution	0.25	2.5
c. Education for the Marine Sciences	0.05	0.5
Department of Defense		
Corps of Engineers		
a. Development of Offshore Facilities	0.15	1.40
Smithsonian Institution		
a. Submersibles	0.2	20.0
b. Great Lakes Ecology	0.2	0.5
c. Marine Aquacultural Station	1.0	20.0
d. Underwater Archeology	0.3	10.0
e. Marine Preserves	0.1	8.0

Table E-2 (Cont'd)

	$ millions First Year FY '70	Total Ten Year FY '70-'80
Water Resources Council		
a. Establishment of River Basin Commission in the Coastal Zone	1.0	10.0
b. National Assessment of Adequacy of Water and Related Land Resources	0.3	3.0
TOTAL NEW FUNDING	29.11	235.11

[1] Duplicates Item 10 of Table E-1

[2] Duplicates Item 3 of Table E-1

[3] Duplicates Item 10 of Table E-1

An Act

To provide for the optimum management and development of the Nation's coastal and estuarine areas through the establishment of State, regional, and local Management Authorities.

Short Title

SECTION 1. This Act may be cited as the "Coastal and Estuarine Management and Development Act."

Statement of Policy

SECTION 2. The Congress finds that man's past actions affecting estuaries and shorelines have been poorly and incompletely planned, unimaginative, and frequently destructive. In view of the many important uses served by these waters and the growing pressures on them, it is imperative that there be sound planning and intelligent management of this vital national resource. It is thereby declared to be the policy of Congress to encourage the conservation, development, and utilization of these areas to the best standards of public good through the medium of State and local authorities with the assistance and cooperation of the Federal Government.

Effect on Existing Laws

SECTION 3. Nothing in this Act shall be construed–

(a) to expand or diminish either Federal or State jurisdiction, responsibility, or rights in the field of water resources planning, development, or control; nor to displace, supersede, limit, or modify any interstate compact or the jurisdiction or responsibility of any legally established joint or common agency of two or more States, or of two or more States and the Federal Government; or to limit the authority of Congress to authorize and fund projects;

(b) as superseding, modifying, or repealing existing laws applicable to the various Federal agencies which are authorized to develop or participate in the development of water and related land resources or to exercise licensing or regulatory functions in relation thereto, except as required to carry out the provisions of this Act.

Definitions

SECTION 4. For the purposes of this Act:

(a) the term "estuarine areas" means an environmental system consisting of an estuary and those transitional areas which are constantly influenced or affected by water from an estuary such as, but not limited to, salt marshes, coastal and intertidal areas, sounds, embayments, harbors, lagoons, inshore waters, and channels.

(b) the term "estuary" means all or part of the mouth of a navigable or interstate river or stream or other body of water, including, but not limited to, a bay, sound, and channel, having unimpaired natural connection with the open sea and within which the sea water is measurably diluted with fresh water derived from land drainage.

(c) the term "coastal area" means the lands, waters, and lands beneath the water in close proximity to the coastline (including Great Lakes) and strongly influenced by each other.

(d) the term "coastal State" means any of the several States which include coastal or estuarine areas within their boundaries. The District of Columbia, Puerto Rico, the Virgin Islands, Guam, and American Samoa shall be treated as States for the purposes of this title.

Title I—Coastal Management Authorities

Creation of Authorities

SECTION 101.

(a) The Secretary of .... is authorized and directed to cooperate with the coastal States for the purpose of encouraging and establishing State Coastal Management Authorities (hereafter referred to as the "Authority").

(b) The Governor of a coastal State may propose, establish, create, or designate, through legislative or other processes he may deem proper, new or existing Authorities whose functions are the accomplishment of the policies and objectives of this Act.

(c) Upon submission to the Secretary of the proposed Authority or Authorities together with the organization functions and powers of the Authority, the Secretary may approve the Authority as consistent with the purposes of the Act.

Form of Authorities

SECTION 102.

(a) The form of the Authority shall be left to the discretion of the participating States. It may range in scope from a Statewide central State agency to a regional commission responsible for a single estuarine system.

(b) In order to be designated a participating State, a State need not designate Authorities to have responsibility for its entire coastal and estuarine areas. A State may establish or designate additional authorities at any time. Each one so designated must meet with the approval of the Secretary in order to become eligible for Federal Funding Assistance under this Act.

(c) In designating Authorities the State is encouraged to give precedence to critical areas identified by the National Study authorized by section 5(g) of the Federal Water Pollution Control Act, as amended, and other broad National Inventories as may be authorized.

(d) The organization and structure of Authorities may vary within a participating State and among States according to the political frameworks within which the authorities have been established.

(e) Two or more States which in the best interests of coastal or estuarine management may wish to establish or designate existing interstate compacts or River Basin Commissions as Authorities may do so if approved by the Secretary as having adequate powers and funding arrangements to accomplish the purpose of this Act.

Functions of Authorities

SECTION 103. The functions of Authorities to meet the objectives of this act are:

(a) To plan for the accommodation of multiple uses of the coastal and lakeshore waters and lands.

(b) To resolve conflicting actions through the means of regulation, zoning, and/or acquisition where appropriate.

(c) To maintain a continuing inventory and studies and to sponsor and otherwise conduct research as a contributing link in decision making processes.

Powers

SECTION 104. In order to achieve its purposes the State and local governments are encouraged to grant the State delegated Authority the following powers

Planning–authority to conduct the research and planning necessary for informed decision-making.

Regulation–power to grant or withhold permits and/or establish zoning for coastal land and water use and, in addition, some authority to require that lands adjoining the coastline be used for purposes compatible with the overall plan.

Acquisition and eminent domain–authority to acquire lands where public ownership is necessary to carry out the plan, and to acquire easements.

Development–authority to provide, either directly or by arrangement with another governmental agency, such public facilities as beaches, marinas, and other waterfront developments that may be required to carry out the plan.

Policy Guidelines

SECTION 105. In reviewing and approving the plans and program of an Authority pursuant to Federal assistance the Secretary shall require Authorities to observe the following standards:

(a) Coastal zones should support the widest possible variety of beneficial uses and be managed to maximize net social return. This means that no single use–such as waste disposal–or class of uses–such as commercial uses–should be allowed to exclude other uses.

(b) As public resources, coastal waters and shorelines should not be permitted to be exploited for private gain if it is accomplished at public expense.

(c) Management authority should represent a balanced approach and should not be dominated by either conservation or economic development authorities.

(d) There must be a mechanism established between the Federal and the State and local governments in the determination of shoreline use within the coastal zone.

(e) There must be an opportunity for public hearings to allow local governments, private interests, and individuals to express their views before actions are taken or decisions are made changing or modifying the coastal zone.

(f) Laws and regulations enacted in the public good must be empowered with a mechanism for enforcement.

(g) Past decisions of a management authority should become a matter of public record.

(h) Any proposed action must not violate the water quality standards established by the States in accordance with Federal law.

(i) In the case of interstate estuaries, the programs of other States must be considered.

(j) The fishing rights of other States must be respected.

(k) Any actions must respect all existing Federal rights within the coastal zones and in the contiguous zone, as well as international agreements.

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Title II—Financial Assistance to Participating States

SECTION 201. General Authorization

(a) The Secretary is authorized to provide financial assistance to participating States for the purposes of this act for (1) planning, (2) acquisition of land, waters, or interests in land or waters, or (3) development and restoration of public lands and waters.

(b) The Secretary shall prescribe such regulations, establish such procedures, and make such arrangements and provisions relating to any performance of the functions under this title, and the use of funds available therefor, as may be necessary in order to assure (1) coordination of the program authorized by this title with related Federal assistance programs, including the Water Resources Planning Act, Federal Aid in Wildlife Restoration Act, as amended, the Federal Aid in Fish Restoration Act, as amended, the Land and Water Conservation Fund Act of 1965, the Commercial Fisheries Research and Development Act of 1964, National Sea Grant College and Program Act, and the Housing Act of 1954 and (2) appropriate utilization of other Federal agencies administering programs which may contribute to achieving the purpose of this Act.

Allotments

SECTION 202.

(a) From the sums appropriated pursuant to section 201 for any fiscal year, the Secretary shall make allotments among *participating* coastal States in accordance with his regulations and the objectives of this act based on (1) the coastal or estuarine area within the proposed region, (2) the need of the State, and (3) the merit of the proposed plan or project.

(b) At the discretion of the State, payments or assistance may be made directly to the delegated State Authority.

(c) Payments to any State or Authority for planning purposes shall cover not more than 50 per centum of the cost of planning.

(d) Payments for operating expenses of an Authority may not be authorized except that the first two years' operations may be funded from planning grant funds.

(e) Recognizing that enforcement action is a vital role, allotments may be paid to participating States as grants-in-aid for enforcement purposes.

SECTION 203.

(a) In addition to grants-in-aid, the Secretary is authorized to enter into agreement with participating States or their delegated Authorities to underwrite by guaranty thereof bond issues or loans for the purpose of land acquisition or land and water development and restoration projects.

(b) The Secretary is further authorized to make payment for the amortization charges and loan interest for the first five years following issue of the bond or loan.

(c) Bond issues under this provision shall not be tax exempt.

(d) Federal allotments under Section 202 in conjunction with guaranteed bond issues shall not exceed the bond issue, or 50 per centum of the total cost of the acquisition or development, whichever is less.

Review

SECTION 204. Whenever the Secretary after reasonable notice and opportunity for hearing to a State Authority finds that—

(a) the program submitted by an Authority and approved under section 202 has been so changed that it no longer complies with the requirements of the State or Authority Plan or the objectives of this Act.

(b) in the administration of the program there is a failure to comply substantially with such a requirement, the Secretary shall notify such agency that no further payments will be made to the State under this title until it is satisfied.

Title III–Miscellaneous

Authorization of Appropriations

SECTION 301. There are authorized to be appropriated not to exceed $5,000,000 annually to carry out the provisions of Title II of this Act.

Part IV

Report of the Panel on Education, Manpower, and Training

Contents

The Panel on Education, Manpower, and Training carried out a year-long review of the Nation's needs for education and training in the marine sciences, and of the present and anticipated manpower situation in marine-related occupations. It was the panel's intent to describe the current situation in quantitative terms and to recommend specific action necessary to implement the Commission's proposed National ocean program from the standpoint of manpower requirements. The panel was forced reluctantly to the conclusion that accomplishment of its objectives was impossible under present conditions.

A basic constraint was the lack of reliable data on (1) the present employment situation in marine-related occupations, (2) current and anticipated demand for persons in these fields, and (3) the projected scope of future education and training programs in marine affairs. There is also a lack of consensus on definitions of job categories and of levels of competence for work in these fields. A recent survey, for example, identified some 5,800 persons employed in marine science and technology programs; yet in fact the number of persons engaged in marine-related occupations (commercial fishermen, shipyard workers, merchant seamen, etc.) may be close to one hundred times that number. Nor is there a close correlation between the persons who have received formal training in marine-related disciplines and those who are actively working in these areas. The transferability factor is strong here: graduates of basic science curricula become oceanographers, space engineers transfer to marine fields, and trained machinists become marine technicians. No studies have been made which quantify such transferability or even seek to determine the percentage of graduates in marine curricula who actually remain in the marine areas.

Since the Nation does not now have the means for assessing marine education and training needs, the panel recommends that within the new oceanographic agency an office be established to develop this capability and to serve a coordinating function for Federal manpower and education activities in the marine field. The panel also recommends that the National Sea Grant Program receive increased funding to a level of $22 million by 1972 and that funding for other Federal marine education and training programs be increased incrementally over the coming years. Such programs should pay close attention to new directions developing in the marine-related fields—coastal oceanography, air-sea interaction, and the need for teachers at the undergraduate and secondary school levels. Greater emphasis should also be placed on mid-career training and on providing post-doctoral education for scientists from other fields who come into oceanography and marine technology.

A staff report on the present status of marine education, training, and manpower is presented in a study entitled, "Education, Manpower, and Training in the Marine Sciences." It is included in this volume as Appendix A, page IV-2 through page IV-14.

Appendix A Commission Staff Study:[1] Education, Manpower, and Training in the Marine Sciences

The staff of the Commission on Marine Science, Engineering and Resources has conducted an extensive review of the present and projected supply and demand in marine education, manpower, and training. It found that reliable data were inadequate or non-existent for many aspects of its task; that programs, particularly at the Federal level, were poorly coordinated; and that the history of the marine sciences over the past decades has been characterized by an emphasis on basic and applied research at the expense of education and training.

The review also found that, at the present, the manpower situation in the marine fields is not critical, although shortages do exist in certain areas, and that it is impossible to predict future supply/demand conditions with any precision.

The demand for adequately trained manpower and the ability of the Nation to cope with the demand are complicated both by the expanding and diverse nature of the field and by the various categories of employment it provides. Some persons work directly in marine science and engineering; others are associated with industries conducted on or in the marine environment–commercial fishing, offshore oil operations, the merchant marine, and recreation. Still another group is composed of naval, Coast Guard, and other uniformed personnel. Although this study is primarily concerned with persons active in marine science and engineering, its interests extend to the other aspects of marine-related activities.

Even within marine science and engineering, job categories and levels of competence are widely diversified, and there is considerable transferability in and out of the marine fields. At the heart of the manpower system is a small core of professionals, with extensive backgrounds in oceanography or marine engineering, although often formally trained in other fields. These people tend to spend all or most of their working years in the marine fields. Other professionals spend only part of their careers in marine-related occupations; their basic training in science or engineering is used for various types of employment. Finally, many ocean specialists, technicians, and craftsmen are mobile; they enter and leave the marine areas according to the relative advantages of other fields of employment. These persons may or may not have received formal training in marine matters; all or most of what is needed for their marine activities may be picked up from on-the-job training or from short courses of instruction.

I. DIMENSIONS OF THE PROBLEM

Before the current situation in marine education, manpower, and training can be assessed, three basic terms must be defined. In this study, "education" is used to include activities in which individuals receive formal instruction as part of a broadly based curriculum that, in most cases, leads to the award of a certificate or degree. "Manpower" represents existing labor force–the number of individuals gainfully employed in occupations directly and indirectly related to marine affairs and, where applicable, their employers. "Training" denotes special instruction designed to improve an individual's occupational skills. Such experience generally does not carry academic credit beyond the secondary school; however, some individuals with long experience can eventually attain professional status without formal education.

This study will consider education and training programs in relation to their quantity, quality, and type. Of the existing data on education, training, and manpower in the marine sciences, much are

[1]This report was prepared by Lewis M. Alexander, with the assistance of Holmes Moore. Acknowledgements are due to Dr. Richard Fleming of the University of Washington Department of Oceanography, consultant; Robert Abel and Harold Goodwin of the National Sea Grant Program; Mrs. Norma Martof of the Committee on Marine Research, Education and Facilities of the National Council; and Arnold Joseph of the Council staff.

concerned with quantity: numbers of persons employed, students enrolled, degrees granted, and projected manpower needs. These quantitative data have tended to be both incomplete and unreliable. Little has been prepared in recent years on quality, either of the preparation being received by students in the marine disciplines or the background of persons working in the marine area in terms of the positions in which they are employed. In years to come both qualitative and quantitative assessment of manpower in the marine sciences will be needed for most efficient use of talent.

Considerations relating to types of programs and personnel are basically classification matters. In the past, terms used to describe work categories in the marine fields have been ambiguous; among these are "oceanographer," "marine scientist," "ocean engineer," and "marine technician."

In 1967, the International Oceanographic Foundation (IOF) completed what is, to date, the most comprehensive inventory on manpower in the marine fields.[2] In its study IOF differentiated two major groups of personnel: (1) those judged qualified for professional work in one or more branches of marine science (training or experience equivalent to a Master's degree or higher) and (2) those engaged in scientific and technical work in marine science but not fully qualified to perform independent professional work—oceanographic and fishery technicians, interns, students at the graduate level, and non-oceanographic engineers or technicians.

In the present study a somewhat different classification is suggested, taking into account persons working in the marine sciences at subprofessional levels and distinguishing between technicians and scientists holding a Bachelor's degree and those without one. The following categories are included:

–*Oceanographer* (biological, chemical, physical, geological, geophysical)—training or experience equivalent to a Master's degree or higher.

–*Ocean engineer* (electrical, mechanical, chemical, sanitary, environmental, industrial, or civil)—training or experience in applied research equivalent to a Master's degree or higher.

–*Ocean specialist*—training or experience in science or engineering equivalent to a Bachelor's degree.

–*Ocean technician*—training or experience equal to an Associate of Arts Degree or two years of post-high school training.

–*Marine craftsman*—formal education through high school. Competency in a marine-oriented skill.

–*Unskilled marine aide*—No formal education requirements. Competency to serve aboard vessels.

–*Common laborer*—engaged in shore-based operations.

–*Non-science professional*—training in the social science or humanities aspects of oceanography beyond the Bachelor's degree.

–*Student or intern.*

The first two categories correspond with the oceanographers and oceanographic engineers of the IOF studies. The next four presumably show up in IOF statistics as well, although under different headings, while the last three categories do not appear in the IOF figures. The classification of "student or intern" encompasses those preparing for employment rather than at work in the marine fields.

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[2] *A Study as to the Numbers and Characteristics of Oceanographic Personnel in the United States, 1967,* Report submitted to the National Science Foundation, December 1967, NSF Contract C469. Of 917 institutions contacted by IOF, 441 returned lists of their personnel. How many remaining institutions were staffed with oceanographic personnel is unknown. When follow-up questionnaires were sent to individuals, 85 per cent returned them.

II. FACTORS RELEVANT TO SATISFYING MANPOWER NEEDS

There are many variables in the components of the current and anticipated supply/demand situation for the marine field–so many that absolutes become meaningless and one can deal only with relationships and trends. The principal problems are: What is the total demand for persons to be employed in the marine fields? What is the supply of such persons? What are the factors affecting their *availability* for employment?

A. Demand

The demand factor may be considered in either of two contexts–one which assumes continuation of present growth rates and conditions or one which assumes adoption of an expanded National marine program. Currently the major demand for personnel in marine-related fields rests with the Federal Government, because of its own manpower needs and because of its funding for research and related activities. The 1967 IOF study found that of nearly 5,000 persons working in the marine sciences (excluding students), 54 per cent were employed by the Federal Government and another 21 per cent worked for universities, most of which receive substantial Federal support. The obvious corollary is that any estimate of demand in marine science and engineering, even over the next few years, depends largely on the extent of the Federal oceanographic effort.

State and local agencies and industry are two other principal sources of employment. IOF found that about 300 persons were employed by State and local agencies in marine-related activities, mostly as fisheries managers or fisheries technicians. A total of 560 was employed in private industry, the majority engineers and technicians.

In years to come, many more personnel may be required by State and local governments in various aspects of coastal zone management. Such persons would need knowledge of planning, economics, law, and political science in addition to oceanography and ocean engineering. In industry there will remain a small but growing demand for personnel trained in marine occupations, at least over the next decade; the rate of growth may well reflect, at least in part, action on the Commission's recommendations.

The Commission on Marine Science, Engineering and Resources, in its recommendations for National action, is cognizant that one basic cost is manpower. Adoption of the Commission recommendations will increase marine-related employment in the Federal sector and among its grantees and contractors; it will further stimulate economic activity in industry, particularly in the area of marine engineering and technology.

Incremental operating costs to implement the National marine program recommended by the Commission have been estimated at approximately $450 million in 1973, $675 million by 1977, and about $850 million by 1980. With a standard yardstick of $50,000 per professional worker in the marine field (a rough average for present costs based on staff study), 9,000 new personnel would be needed in marine-related fields by 1973, another 4,500 by 1977, and 3,500 more by 1980–an increment of 17,000 persons over the next 11 years in the marine fields.

Demand projections keyed solely to a single budget cannot reflect the many variables which will actually be encountered in staffing to implement an expanded marine program. In the initial phases of the program–while facilities and equipment are being acquired and plans developed–somewhat larger expenditures may be expected per professional worker than during its latter phases when a full complement has been assembled. These early phases may also see a greater reliance on persons whose training has not been specifically in marine fields. However, the application of such "rules of thumb" as the $50,000 factor provides at least an order of magnitude starting point to more detailed analysis of manpower requirements.

Manpower Implications of Commission Budget Projections

Program Categories	Est. 1980 Budget Increment[1] (millions of $)	Categories of Professional Personnel[2]				
		Oceanographer	Ocean Engineer	Ocean Specialist	Nonscience Professional	Total[3]
Research and education	$220	2,000	1,000	1,000	400	4,400
Specific technology programs	210	400	2,500	1,000	200	4,200
National projects	70	150	800	350	100	1,400
Fundamental technology	250	1,750[4]	1,500	1,400	350	5,000
Mapping, charting, and surveys	40	50	550	150	50	800
All other	60	150	200	500	350	1,200
Total	$850	4,500	6,550	4,500	1,450	17,000

[1] Excludes capital outlay.

[2] International Oceanographic Foundation categories. See page IV-3 for definitions. For purposes of this exhibit, the definitions should be construed broadly to include persons of various backgrounds when working on ocean-related problems regardless of the nature of their primary interests and employment.

[3] Total professional personnel computed on a "rule of thumb" formula of $50,000 per professional person. The assignment of this computed number to the various professional categories has been made entirely on a judgmental basis.

[4] Includes personnel trained in basic scientific disciplines at the M.S. level or higher working on fundamental problems relating to materials, environmental effects, biomedicine, and so forth.

B. Supply

The number of natural scientists in the United States, as reported by the Bureau of Labor Statistics, is about 400,000, and the number of professional engineers, according to the National Academy of Engineering, is about 500,000. From these pools and from the graduating classes in science and engineering must come future oceanographers, ocean engineers, and ocean specialists. Significant contributions are made by the marine education programs. In 1967-1968 over 1,400 individuals received either Bachelor's or higher degrees in marine science in the United States. How many accepted employment in marine-related occupations is not known.

The extent to which development of marine science and engineering activities depends upon persons trained specifically in marine fields is very difficult to assess. No systematic data now exist on the nature of the formal training of persons employed in marine fields. The marine area is obviously responsible for educating some portion of the personnel it needs; it cannot rely entirely on transfers from other disciplines.

Not all persons receiving ocean science and engineering degrees, particularly at the undergraduate level, can be expected to remain in the marine field. Training in marine curricula generally is broad enough to permit transfer to other fields. Furthermore, many students taking advanced degrees intend to teach. As appeal of the marine environment continues to grow, more teachers will be needed at both the undergraduate and secondary school levels, for more students will be seeking one or more "general education" courses in marine matters.

The expectation of a sharp expansion of marine programs has brought increased enrollments in marine curricula, and all indications are that the number of graduates in marine fields will accelerate over the next few years, perhaps outpacing demand. Such a situation is not necessarily unhealthy. An oversupply of graduates would most likely mean that the more competent would remain in the marine fields and that others would transfer to different occupations.

Consideration must be made for the "lead-time" necessary to produce professional personnel—an average of 8 to 10 years after high school for the Ph.D, and at least 6 years for the Master's. Even if immediate action is not taken on the Commission's recommendations for an expanded program, it appears probable that within a 10-year period the demand for personnel in marine fields will increase. Continued growth in the intake into marine education should therefore be maintained at this time to assure that trained personnel will be available to staff such activities as the nation may wish to undertake in the seas.

In addition to the overall supply, attention is needed to assure the supply of certain specialists. The National Academy of Sciences Committee on Oceanography (NASCO) reports current shortages in physical and chemical oceanographers and in taxonomists. NASCO also notes a shortage of ocean technicians and marine craftsmen in scientific research and development, and indications are that this shortage will intensify over the next few years. Several small programs have been initiated for formal training of ocean technicians for subprofessional positions in scientific research, exploration, and cartography, which complement the supply of on-the-job trained technicians. Many technicians and craftsmen, however, will necessarily have to be recruited from other fields in competition with other types of employment.

Through the Federally sponsored Economic Opportunity program, training is being offered to make persons available for marine activities support services. These programs are new and relatively untested.

The supply of non-science professionals is extremely small, but so too is their demand. The need for such persons was recognized in the President's Science Advisory Committee Report, *Effective Use of the Sea.* PSAC urged establishment of Marine Study Centers, whose role would be:

not only to foster studies on applications of science and technology to the sea, but also to relate them to underlying natural sciences and to social sciences—economics, sociology, psychology, politics, and law—as they are affected by and in turn affect occupation and exploitation of the sea.

The National Sea Grant Program, oriented in part toward similar ends, has been aiding institutions for education and training in these applied aspects of oceanography.

During the past decade, the availability of facilities for education and training in the marine fields has grown, but so too has the number of students. In 1967, 45 U.S. institutions offered a Ph.D. in marine and marine-related sciences and engineering, compared to 12 in 1962; 53 institutions offered a Master's degree in 1967 against 14 in 1962; and 32 offered a Bachelor's degree compared to 3 in 1962.

The Committee on Marine Research, Education, and Facilities of the National Council on Marine Resources and Engineering Development recently surveyed education and training in the marine fields. Compared with 6,101 students enrolled in marine science programs at the undergraduate and graduate levels in 1967-68, 1,597 were enrolled in 1961-62; 858 graduated in the marine sciences in 1966-67, and 407 graduated in 1961-62.[3]

Undergraduate and graduate students enrolled have been increasing at about 25 per cent per year (doubling time about three years), and the number of degrees granted has been increasing at about 20 per cent per year. If the annual increase in enrollment continues for the next decade, the number of undergraduates will grow from 1967-68's total of about 3,500 to over 35,000 in 1977-78, and the number of graduates will increase from 2,600 to 26,000. It is unreasonable to expect the rate to increase in this fashion over the entire period, but the statistics indicate present trends.

The following graph, taken from a study completed in June 1968 by the Committee on Marine Research, Education, and Facilities, shows enrollees and graduates in six major types of marine curricula between 1961-62 and 1967-68. Figures for graduates in 1967-68 are estimates.

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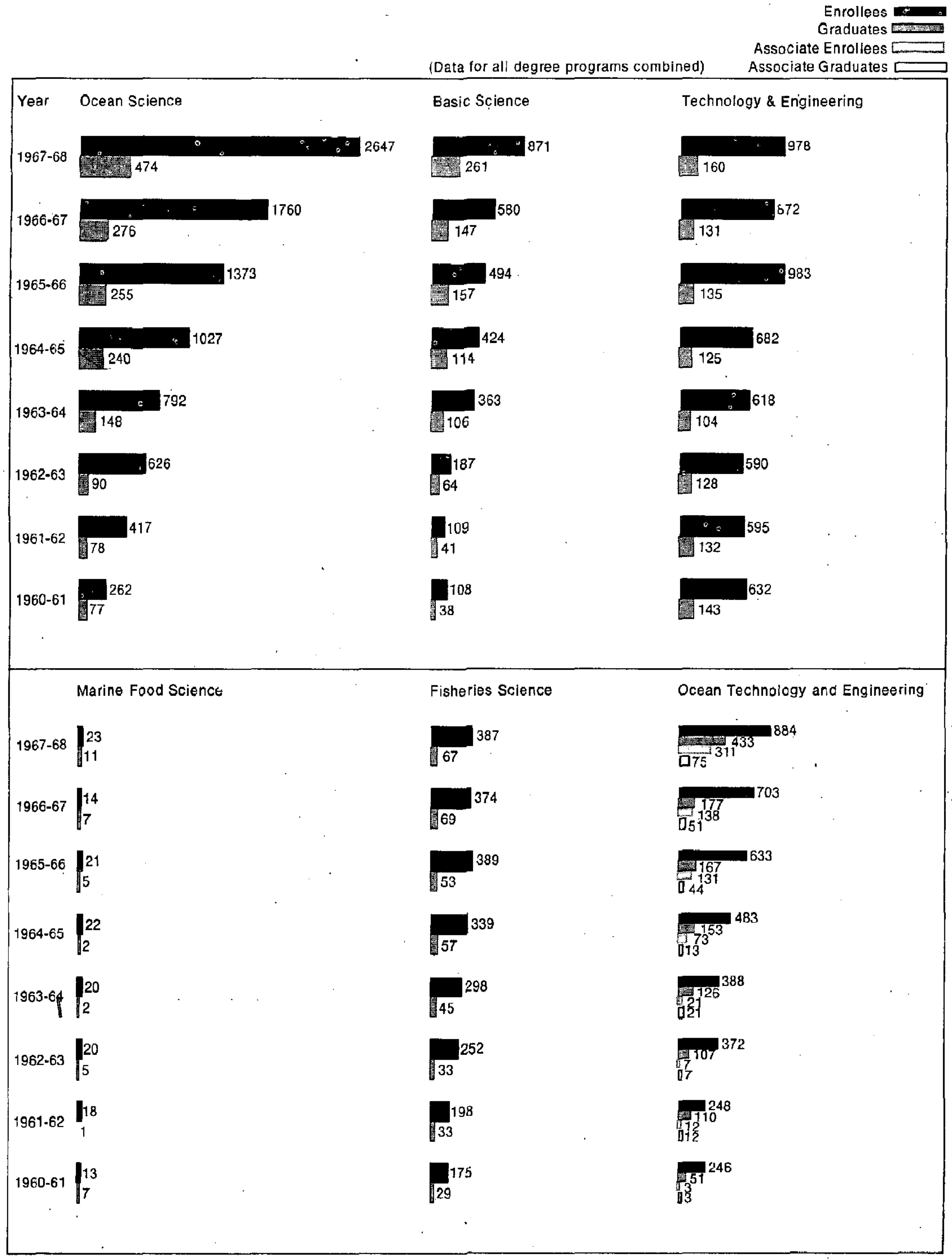
[3]The 10 institutions on the Council of Laboratory Directors (representing the largest marine science universities in the Nation) reported a 10-fold increase in 1967 over 1960 in full-time graduate school enrollment and Master's and Ph.D. degrees granted.

Graduates and Enrollees in Marine Science Education Programs



C. Availability

Marine-related occupations compete with other endeavors in attracting skilled personnel. Although many trained workers plan to spend their work lives in the marine environment, there are also many

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exceptions. If marine science, engineering, and technology are intellectually and financially attractive enough relative to other fields, most trained in the field will elect to remain, and many scientists and engineers trained in other fields will be attracted. Employment opportunities will also lure specialists from abroad.

Within certain specialized fields, transferability of marine sciences is limited. Such would be the case in various research activities in fisheries biology or taxonomy-systematics.

In any profession availability is difficult to project. Involved are salary and promotion opportunities, location and conditions of employment, relative appeal of the profession within the total National culture, interest or intellectual stimulation offered, and competition from other professional areas. Appeal of the marine sciences during the past few years may be gauged by the upward trend in applications to education and training institutions and the increasing number of professionals and skilled workers transferring to marine-oriented fields. Part of the increase may be due to the attention paid to the marine sciences in the United States and to the very small number employed in the marine areas until a few years ago. Admittedly, the sea has always attracted what has been referred to as "sea people," but new vehicles, new exploratory opportunities, and above all, a new cultural appeal invite the young. In addition, older scholars and technicians are drawn by the marine environment's vast problems, which only recently seem timely and capable of solution.

The appeal of marine occupations must be assessed in terms of other forms of employment, of numbers and occupational types, and of levels of competence of those seeking marine-related employment. It appears that marine science activities are sufficiently attractive in reference to supply and demand that unusual steps (economic or otherwise) are not now needed to draw people into the marine fields. But the level of effort recommended by the Commission may require additional incentives.

III. EDUCATION AND TRAINING CURRICULA AND FACILITIES

A. Programs and Enrollments

The graph illustrates an accelerating demand at all levels for instruction in the marine areas. Because of the lead time required for their development, facilities, rather than student interest, will be the limiting factor, at least over the next decade, with respect to marine education and training growth. Of the several hundred applications received each year by the major educational centers, only a few hundred can be accepted.

In part, the applicant's grades and adequacy of preparation are decisive factors, but often limitations of space and funds for assistantships or stipends are of equal or greater importance. In the past, most funds in marine science and technology went into research; not enough have gone into teaching, with the result that the Nation is now short of competent teaching personnel.

B. Educational Objectives and Criteria

Four levels of marine education and training now exist: graduate and postdoctoral education, undergraduate studies, mid-career instruction, and marine technician training.

Curricula in graduate and postdoctoral education are relatively new compared to those in other subjects. The scientific content and the technology involved are developing and changing rapidly. Educational activities should be encouraged to experiment in subject matter and in methods of presentation. One objective should be to provide *breadth*—to develop generalists with a broad understanding, who can deal with the science of the environment and with the many interactions existing between man and his environment. Another objective should be to develop *adaptability* and *ingenuity*. Science and technology are advancing at such a rapid pace that today's student must soon meet, identify, and solve problems never introduced in the classroom. These comments, applicable to other fields, are particularly appropriate for marine sciences because of their expanding scope and interdisciplinary nature.

There are several approaches to professional training in this field. Some authorities believe that a Bachelor's or even Master's degree in oceanography may be less meaningful in an oceanographer's career than one in biology, chemistry, physics, or other basic science. A broadly trained oceanographer may move about freely in the marine sciences. In contrast, some educators note the time saved by the undergraduate student early introduced to the marine curricula. In such a rapidly expanding field as marine science and technology, there is room for both types of educational experience.

At the graduate level, two types of programs should be offered—one in which a student spends an average of four to six years as an aide or assistant in the research activities of his major professor and one in which he concentrates on course work and his own research, thus completing his formal education in the minimum time. Here is a problem endemic to many fields but particularly germaine to the marine sciences because of the tradition that a graduate student spends years of apprenticeship before receiving his degree. Also, financial assistance to the student is usually conditioned upon his performing a research assistant's tasks. More fellowships are needed for aiding graduate students wishing to pursue a more intensive program of study in order to reduce the time needed to meet degree requirements.

Opportunities for postgraduate study by persons with advanced degrees in the basic sciences or engineering are required for those who wish to work in the marine sciences. The National Academy of Sciences has noted the need for ocean scientists who can bridge the gap between the classical and the marine sciences. The trained scholar with feet in both camps is much in demand, and the postdoctoral scientist entering oceanography with a Ph.D. degree in one of the basic sciences meets this need. Ample funds should be available for this type of advanced student to work at major institutions throughout the Nation.

At the undergraduate level, student demand must be met for general courses in marine subjects and for establishing majors in these fields. Baccalaureate degrees in marine science were offered at five institutions in the 1967-68 academic year and three Bachelor's programs in ocean engineering were offered. In addition, two institutions offered Bachelor's degrees in fisheries. Since the need for ocean specialists is growing, particularly for ocean survey work, holders of Bachelor's degrees should be able to find suitable positions for some time. Other graduates may be expected to become teachers at the secondary level or, with further training, at the college level.

At another educational level are the mid-career training programs, particularly for those in the marine science field whose jobs are so limited as to provide a narrow perspective of marine developments. Many Federal employees are within this group, along with business and industry administrators, teachers, and researchers concentrated on one highly specialized aspect of the field.

For such persons, refresher courses might be provided by the National Science Foundation (NSF); Office of Naval Research; the Department of Health, Education and Welfare, etc., possibly during the summer, including some shiptime experience. Federally funded sabbaticals also would make possible longer-term, mid-career training programs.

We are conscious of the need for different kinds and levels of training, and this study recommends that funds be made available in the annual Federal oceanographic budget specifically for mid-career programs at National and regional university centers. These programs would provide opportunity for instruction, discussion, experience, and formulation of plans and policies in marine-related matters. Participants would come from government, industry, business, and the universities for periods of a week or two to several months. The programs might provide opportunity to spend time aboard ship for instructional cruises.

At a fourth level are the technical training programs of two years' duration or less. The first program of this type began in 1959; several others now exist, and the number of graduates, although small, is gradually rising. Within the next few years, the number of such technical training programs is expected to increase.

Officials at existing institutions believe that marine technician training is specialized, implying that transferability is sometimes difficult and that some shorter training courses do not qualify as adequate preparation for a technician's specialty. The success of these institutions has prompted other schools to begin technician training, including a two-year course started recently for fisheries technicians.

The term "marine technician" should be defined more carefully, since specialists at this level are important to marine development. As in the case of ocean engineers, a new and expanding field has developed here—a field whose dimensions cannot now be determined exactly.

In recent years a start has been made toward training marine technicians in Government anti-poverty programs. There may be little relationship in some of these programs between the trainees' interest and competence for marine work and their acceptability for marine technician courses. But in many instances at least elementary instruction can be given (to be followed by on-the-job training) in marine-related pursuits both at sea and in such shore-based enterprises as the National Ordnance Laboratory, Naval Electronics Laboratory, Naval Research Laboratory, and the Bureau of Commercial Fisheries.

C. Education and Training Facilities

Physical facilities required for marine education and training include shore laboratories (together with classrooms, libraries, etc.) and oceanographic vessels. An obvious correlation exists between the use of laboratories and ships for education and training and for research. Completely separating the two uses is not fruitful, but research activities should not always be given priority for laboratory or ship use.

As more students enter the marine sciences, the programming of laboratories and ships for training use will require increased attention. Provision will need to be made in planning facility use for the lead time necessary to incorporate special laboratory or ship activities into the teaching program—an essential factor in institutional planning.

Oceanographic institutions may have the necessary capital equipment but not the funds or personnel to maintain it. A partial answer may lie in the use of ships (and to some extent laboratories) by other institutions on a cost-share basis, particularly those inland and/or those with a relatively small marine science program.

The need for facilities, particularly ships, affects especially the quality of training of marine technicians and indeed to mid-career programs as well. Perhaps one distinguishing feature of good marine technician training programs will be experience in ship operations.

D. New Directions in Education and Training

There are several areas in which new needs for educational curricula will certainly develop. One is in coastal oceanography. During the coming years the Nation will increasingly turn to the multiple use and management of its inshore waters—estuaries, bays, deltas, and territorial waters along its more than 13,000 miles of coastline. This interest will create need for more "coastal" marine scientists—biologists, chemists, sedimentologists, shellfish ecologists—and for engineers to solve the problems of this complex ecological region at Federal, State, and local levels.

Within the field of basic marine sciences, new forms of emphasis will develop, as in using our improved knowledge of the marine food web to increase sea productivity and in advancing our understanding of air-sea interaction toward more accurate and extended environmental prediction. In marine technology, efforts will increase toward utilization of the Continental Shelf for its living and non-living resources and toward extending man's capability to explore and exploit the deep oceans at greater depths.

A third area will be in the social sciences, creating the need for planners, economists, political scientists, marine geographers, lawyers, and behavioral scientists. The following suggests social components:

—Marine economics

Resource economics, fisheries, shipping, recreation, marine mining, land use economics, economics of marine dependence.

—Marine law

International law of the sea, maritime laws and regulations.

–Marine geography
Coastal geography, marine orientation studies, geography of the oceans.

–Marine planning

–Marine institutions and policies
Government and marine affairs, international politics and the ocean, maritime history.

Few of these fields are well-developed conceptually. There are only a small cadre of experts and limited courses of instruction. The Sea Grant Program is seeking methods to assist in the growth of these disciplines. In addition, State and private funding should be directed toward education and research on the impact of the marine environment on the Nation's socio-economic and political structure.

E. A Suggested Hierarchy of Institutions

The field of marine science and engineering will become larger and more complex in coming years; thus marine education and training programs are likely to become more costly. To conserve teachers and facilities and to raise the quality of education, particularly at the graduate level, it should be possible to establish a system of graduate schools in marine science and engineering, starting with a few educational centers for nationwide use.

Such centers might be associated with the university-National laboratories, as recommended in the Panel on Basic Science Report. They could provide Ph.D. and some Master's training in all aspects of their fields. Although training would be closely associated with the centers' contract research activities, it would not be so limited. As National education centers, they would receive special funds as a part of the Federal ocean program. Needed facilities could be shared with other institutions engaged in marine education programs.

At the next level would be regional centers, offering both Ph.D. and Master's programs. These centers could both concentrate on regional marine science problems and give more attention to Master's programs than the National centers. Like the National institutions, they would have their own oceanographic vessels for training and research and would receive commensurate Federal support.

On a third level are institutions with smaller programs specializing in one or two aspects of oceanography or ocean engineering. These institutions might not have their own research vessels. The number of institutions would vary with demand, and location need not be limited to coastal areas. They provide an opportunity for original and significant applied research without the capital investments needed by the larger oceanographic and ocean engineering institutions. The need for applied research programs has already been recognized by the Congress in authorizing the Sea Grant Program.

At a fourth level are courses in marine-related fields at technical and secondary schools. It is important that at the secondary level the better students be encouraged to specialize in marine fields. To this end, competent teachers, good textbooks, and laboratory facilities and equipment are necessary.

IV. FUNDING ARRANGEMENTS AND NEEDS

Means by which Federal funds are made available are: (1) direct grants or loans for education and training, (2) research and development grants and contracts to investigators employing graduate students, under which continued graduate education supported through research activities, and (3) in-house education and training within Federal agencies.

A. Existing Programs

Funds for education programs are supplied principally by HEW and NSF (both directly and through the Sea Grant Program). HEW maintains several avenues for funding, through loan programs, the

National Defense Graduate Fellowship Program, and Title III of the Education and Secondary Education Act of 1965, which permits the Federal Government to make grants to elementary and secondary schools for developing new programs in the marine science field. In FY 1968, HEW spent some $280,000 in support of 49 graduate fellows in the marine sciences and about $360,000 to train technicians for the fishery trades and industry. NSF also supports graduate and undergraduate students in the marine sciences; in addition, it supports faculty member research training and development of new courses and curricula in marine science. An even more important contributor to graduate education is the Navy, through its research contracts.

The National Sea Grant Program, authorized in October 1966, has three major objectives: training and education, research programs in various fields relating to development of marine resources, and advisory services in marine resource development. Funding for training and education is directed toward producing manpower necessary to marine resource development: marine technicians, ocean engineers, and other technologists. Of a total budget in FY 1968 of $5 million, approximately $2 million were allotted to education and training.

The Sea Grant Program provides matching funds to institutions to cover up to two-thirds the cost of specific projects. The two principal forms of Sea Grant funding are institutional support and project support. Within the framework of institutional support, the Program hopes by 1974 to have established 17 to 20 Sea Grant colleges–centers of competence in solving marine resources problems.

During its first year of operation (FY 1968), the Sea Grant Program funded six institutional programs and gave small grants to two other institutes for planning activities prior to submission of FY 1969 institutional proposals.

The Program also funded several project grants at non-Sea Grant institutes. Among the project titles were "Development of New Subjects for Ocean Engineering Graduate Program," "Planning for American Junior College Involvement in the Training of Marine Technicians," and "Improvement and Expansion of Marine Technology Curricula"–illustrations of Sea Grant's concern for education and training problems.

Sea Grant has also been seeking to involve industry, as well as institutions, in its programs. Industry might provide fellowships and scholarships to institutions enjoying Sea Grant sponsorship; it might sponsor cooperative educational on-the-job training programs between Sea Grant institutions and industry.

Another source of Federal support in training marine technicians is the Department of Labor. Through the Manpower Development and Training Act, Labor is spending several million dollars each year to train marine specialists: butchers, bakers, cooks, stewards, and shrimp and fishing boat crewmen, including factory ship crewmen. The Department is also funding union training of merchant marine officers. The Office of Education, in cooperation with the Department of Labor and the Office of Economic Opportunity, has initiated a pilot program to train hard core unemployables as marine technicians.

Other Federal agencies are also involved in education and training. The Smithsonian Institution supports a few postdoctoral students in marine biology, and the Department of the Interior funds several doctoral candidates working in fisheries biology. The Atomic Energy Commission contracts for basic research grants in the marine sciences. In-house training is funded by the Navy, the Coast Guard, the Environmental Science Services Administration. The Navy has its own post-graduate marine sciences school in California. The Maritime Administration operates the Merchant Marine Academy at King's Point, New York, and several States support their own merchant marine academies. But within the total complex of marine-related education and training activities, these "internal" contributions to the total manpower pool are minor.

State programs and industry are another source of funds for education and training. But their contributions are not large. In coming years, as the cost of graduate education continues to increase, a matching funds arrangement between the Federal Government and State or local agencies may need to be developed. As noted earlier, private industry has not yet been active in such funding in marine sciences and engineering; presumably a substantial increase must wait until industry can see the possibility of greater returns from its marine operations.

B. Coordination of Federal Activities

The Interagency Committee on Oceanography and more recently the Committee on Marine Research, Education, and Facilities of the National Council have made many contributions to improved coordination of Federal activities in support of marine education and training. Nevertheless, one of this study's major conclusions is that a stronger mechanism is needed for obtaining and analyzing data on education and training programs and manpower needs and for coordinating Federal activities to support the education and training of marine personnel.

An urgent need is for a better system for the collection, analysis, and dissemination of information relating to training programs and needs. Data which have been assembled are subjected to inordinate delay before release to the public. In a field as small and as vital as the marine sciences, it should be possible to maintain and publish comprehensive statistics on manpower; on Federal, State, and local funding; and on education and training programs.

This study therefore recommends that a Marine Statistics Center be established within one Government agency, that this office have a separate staff and budget to carry out its responsibilities, and that other Federal agencies be directed to coordinate their activities with this center and to supply it continuously with statistics of their own organization's activites in the marine area.

A program for marine education and training should be established within the context of the National plan recommended by the Marine Science Commission. The program need not have a central funding function; in fact existing Federal funding arrangements, or a system approximating them, appear adequate. But one Federal agency should contain a central coordinating body to study total needs, balance Federal agency funding activities, and prepare and administer a National marine education and training plan consistent with changing needs in the marine environment. Hence it is recommended that an Office of Marine Education, Training, and Manpower should be established with responsibilities to:

–Organize and maintain a Marine Statistics Center to coordinate marine education and training facilities within the Government and to serve as a clearing house for applications to graduate and undergraduate programs in marine science and engineering. The Center would maintain an inventory of Federal and non-Federal funding efforts, keep funding agencies informed of other organizations activities, and maintain an inventory of shore facilities and vessels used for education and training programs. It would systematically analyze manpower trends in marine-related activities and would issue periodic projections on the nature and scope of marine education and training efforts.

–Be responsible for evaluating manpower and educational statistics and programs for projecting marine manpower needs, and for planning and recommending programs to provide enough competent personnel.

–Serve as a coordinating body for scheduling use of Federally funded, shore-based or ship facilities by two or more institutions.

C. Future Funding Needs

This study does not recommend that an emergency program be undertaken at this time in marine education and training. It recognizes the need for increased emphasis in certain aspects of the field and for provision for more ship and shore-based facilities for education and training activities. It is also cognizant that the current rate of annual growth of the marine science effort in the Nation may, before long, begin to rise sharply in response to the Commission's recommended program and/or to new sources of economic wealth in the oceans. Increased demand for trained personnel in various marine categories will strain marine institutions' education and training facilities, but there is no indication that these institutions will not be able to adjust to such long-term demands.

Assuming a steady annual increase in the Federal commitment to marine education and training approximating that of the past few years, the demand by employers for personnel should be met. However, program implementation will be difficult if a proliferation of new educational institutions with high initial costs for buildings and capital equipment continues without a corresponding increase in the total Federal budget for marine education and training. Accordingly, primary funding emphasis by the Government should be placed on expanding and improving existing marine science centers. The following more specific recommendations are offered:

1. The Sea Grant College Program should receive increased funding to a level of $22 million by 1972. Funding for other Federal marine education and training programs should be increased incrementally over the coming years. Such programs should pay close attention to new directions developing in the marine sciences-coastal oceanography, air-sea interaction, and undergraduate and secondary school level interest. Greater emphasis should also be placed on mid-career training and on providing post-doctoral education for scientists who come into oceanography and marine technology from other fields.

In "non-science" areas addressed by the Sea Grant Program, increased funding is necessary, for as America undertakes a National ocean program, all aspects of society have a right to involve themselves in its affairs and to benefit from its development.

2. Legislation should be enacted to permit the Sea Grant Program to make grants for the ships and laboratories necessary to support the program's objectives. This amendment to the present Sea Grant statute also has been recommended by the National Academy of Sciences Committee on Oceanography.

Both in this and in the other Federally funded programs, education and training must be clearly identified in future budgets. Too often research overshadows education and training needs. Also needed is development of cooperative arrangements between major marine laboratories and universities that desire marine science programs but their own facilities. A percentage of future National funds for marine-related research and development facilities should be specifically allocated to education and training programs.

3. The Federal Government should adopt a funding policy designed to create a small number of National centers for marine education and training, adequately provided with facilities and teaching staffs to serve as pace-setters in preparing personnel for work in marine-related fields. There would be a few institutions for specialized instruction in the marine sciences.

In all programs to support marine education and training, greater attention is needed to provide continuing financial support. Basic science, in particular, does not produce "results" on a budget cycle. Although the Congress may be unwilling to commit itself to underwriting long-term education and training projects, those who present oceanography's case to the Congress each year should be prepared to stand behind carefully selected programs so that these programs will receive necessary support each year.

Education and training are vital components of the Commission's recommended National ocean program because of the growing need for marine scientists, engineers, and technicians and for program managers, policy coordinators, and others associated with the organizational aspects of marine affairs. Unless greater attention and support are received by the whole area of marine education and training–unless far greater investment than now planned is directed toward marine education and training–or unless the Nation is willing in an emergency to pay the penalties of a crash program like that during World War II, serious manpower deficiencies may develop which would impede the implementation of the National program to make more effective use of the sea.

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